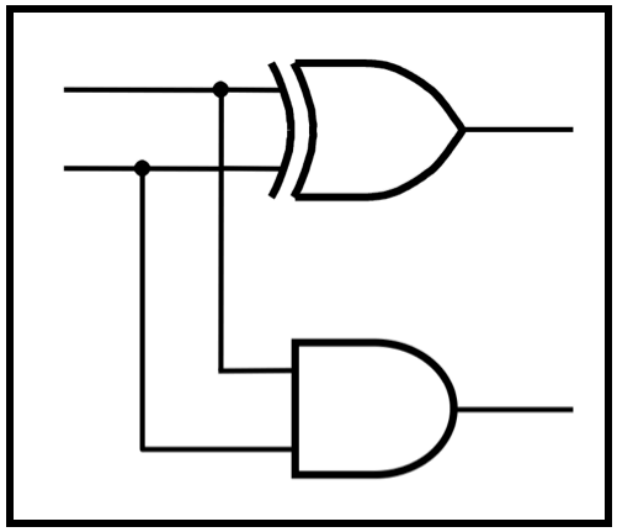


CprE 281: Digital Logic

Instructor: Alexander Stoytchev

http://www.ece.iastate.edu/~alexs/classes/

Register Machines

CprE 281: Digital Logic
Iowa State University, Ames, IA

Administrative Stuff

- **Homework 12 is due today @ 10 pm**
- **Homework 13 is due next Monday @ 10 pm**

Administrative Stuff

- **The Extra Credit Lab is due next week during your regular lab time, at the same time as your lab 13.**

Administrative Stuff

- **The FINAL exam is scheduled for**

  Wednesday Dec 13 @ 2:15 – 4:15 PM

Final Exam Format

- **The exam will cover: Chapter 1 to Chapter 6, and Sections 7.1-7.2, register machines, and i281 CPU**
- **Emphasis will be on Chapter 5, 6, and 7**
- **The exam will be closed book but open notes.**
- **You can bring up to 5 pages of handwritten or typed notes.**

Final Exam Format

- **The exam will be out of 135 points**
- **You need 95 points to get an A on this exam**
- **It will be great if you can score more than 100 points.**
  - **but you can't roll over your extra points ☹**

Topics for the Final Exam

- K-maps for 2, 3, and 4 variables
- Multiplexers (circuits and function)
- Synthesis of logic functions using multiplexers
- Shannon's Expansion Theorem
- 1's complement and 2's complement representation
- Addition and subtraction of binary numbers
- Circuits for adding and subtracting
- Serial adder
- Latches (circuits, behavior, timing diagrams)
- Flip-Flops (circuits, behavior, timing diagrams)
- Counters (up, down, synchronous, asynchronous)
- Registers and Register Files

Topics for the Final Exam

- Synchronous Sequential Circuits
- FSMs
- Moore Machines
- Mealy Machines
- State diagrams, state tables, state-assigned tables
- State minimization
- Designing a counter
- Arbiter Circuits
- Reverse engineering a circuit
- ASM Charts
- Register Machines and programs for them
- ALU, PC, and control for a simple processor (i281 CPU)
- Assembly and machine language (i281 assembly)
- Something from Star Wars

Reading Material for Today

- **“The Seven Secrets of Computer Power Revealed” by Daniel Dennett.**

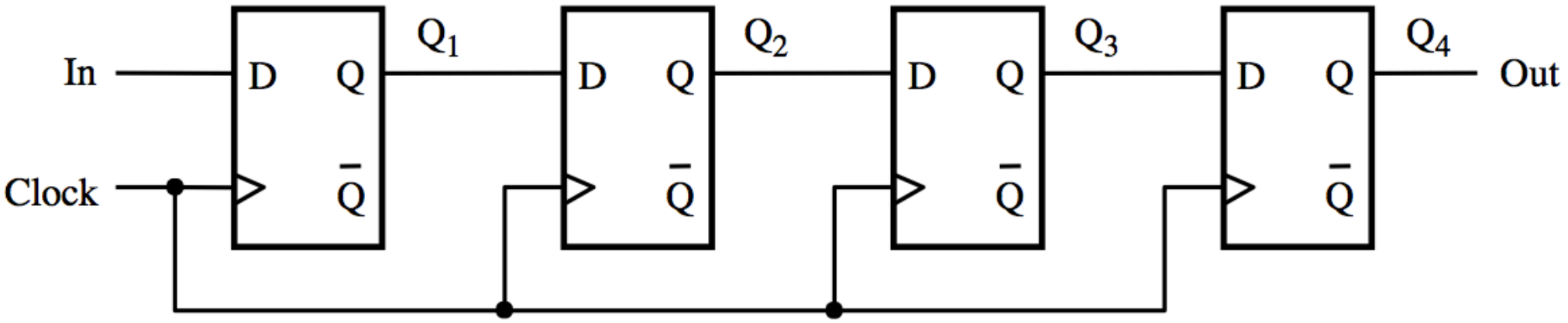
- **This is Chapter 24 in his latest book “Intuition Pumps and Other Tools for Thinking”, 2013**

Reading Material for Today

- **“The Seven Secrets of Computer Power Revealed” by Daniel Dennett.**
- **This is Chapter 24 in his latest book “Intuition Pumps and Other Tools for Thinking”, 2013**
- **Chapter 24 in reverse is: 42!**

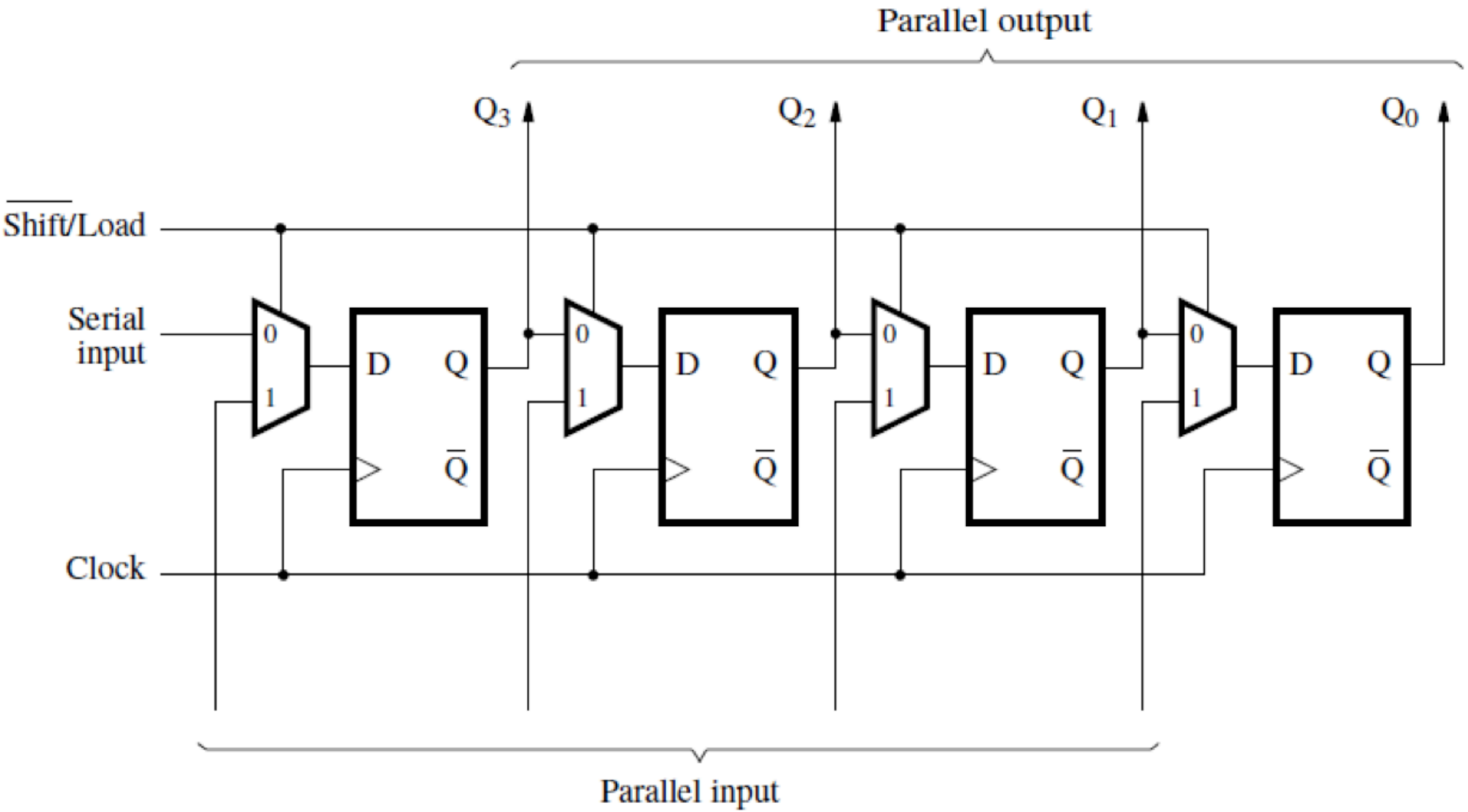
What is a register?

What is a register?



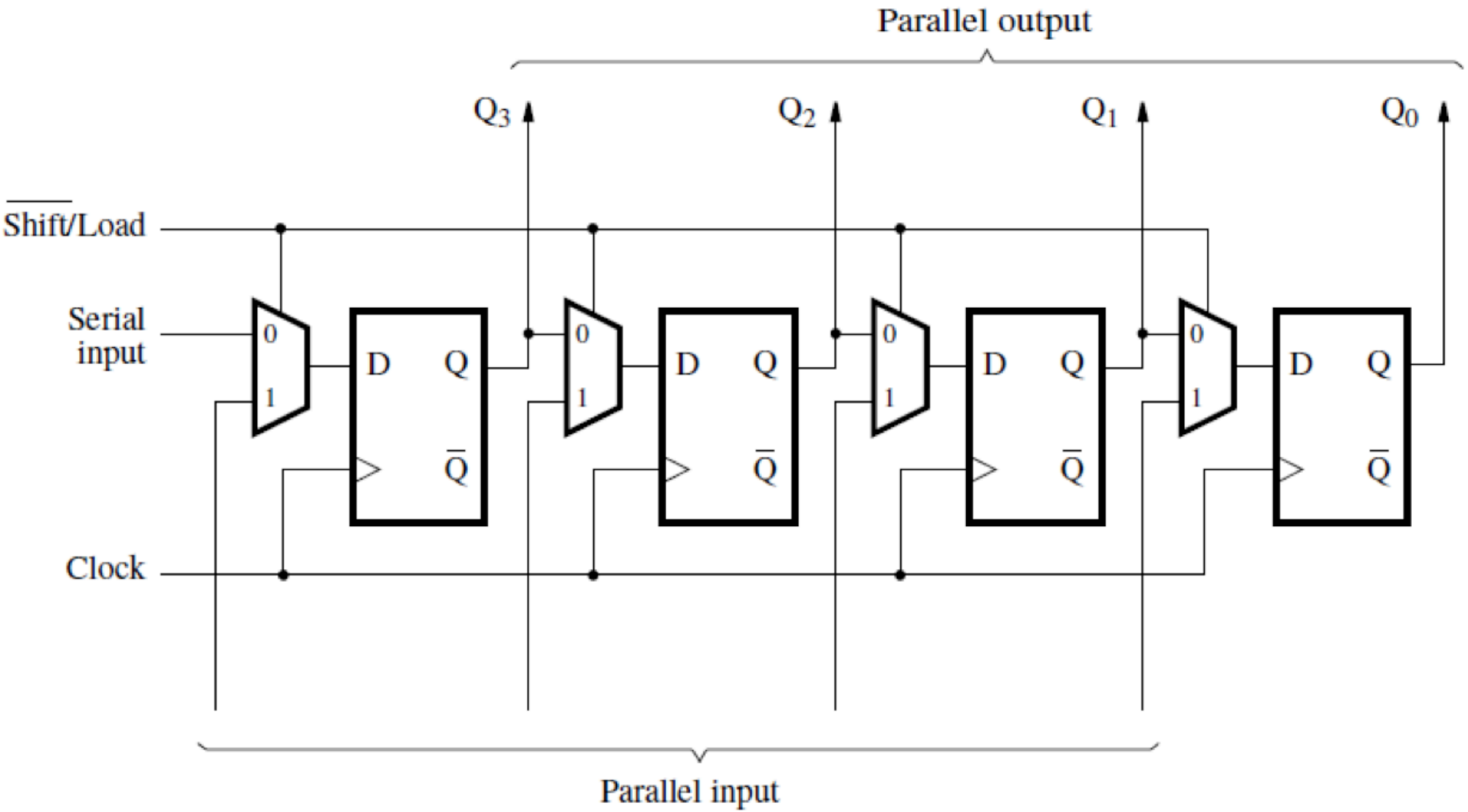
[Figure 5.17 from the textbook]

What is a register?



[Figure 5.18 from the textbook]

What can be stored in this register?



[Figure 5.18 from the textbook]

We Need a Simpler Abstraction

What is a register?

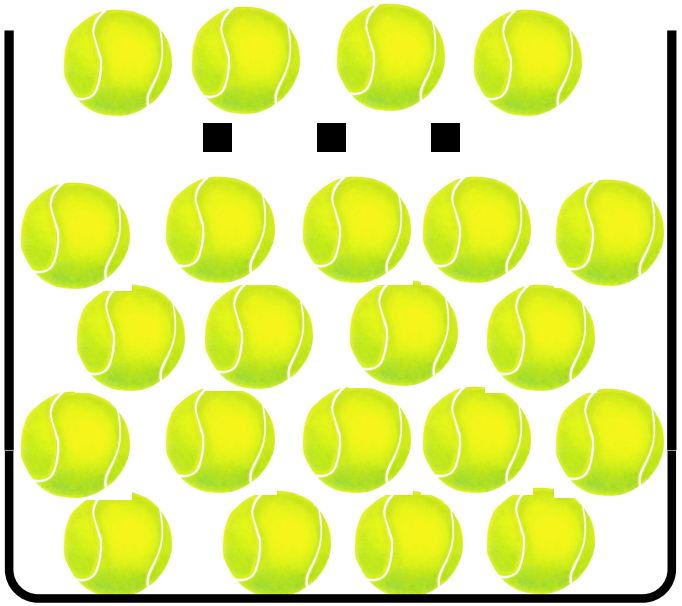
What is a register?

What can be stored in this register?

What can be stored in this register?

How many balls can be stored?

How many balls can be stored?



Infinitely Many

What is a register machine?

What is a register machine?

What is a register machine?

Register 1 Register 2 Register 3

The registers are numbered

What is a register machine?

Register 1 Register 2 Register 3

The registers are numbered and each could store a different number of balls.

Things to Notice

- **There could be many registers, not just three, as long as they are finitely many.**
- **The address of each register is an integer.**
- **Each register stores an integer number of balls.**
- **Storing 3.14 balls in a register is not possible.**

In addition to the registers there is also a processing unit

In addition to the registers there is also a processing unit

- It operates on the registers by changing their contents
- The operations are ordered sequentially and given a number (just like line numbers in BASIC)
- There are only three possible operations
  - Increment a register and go to another step
  - Decrement a register and go to another step
  - End

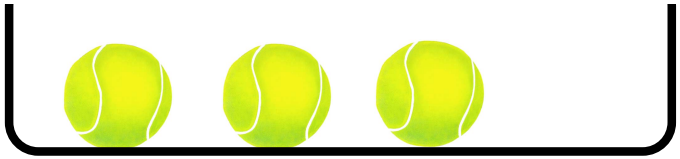
Two Basic Operations
(that can be performed on a register)

- **Increment the contents of a register by 1**
- **Decrement the contents of a register by 1**
- **In both cases the address of the register must be given**

Incrementing a Register

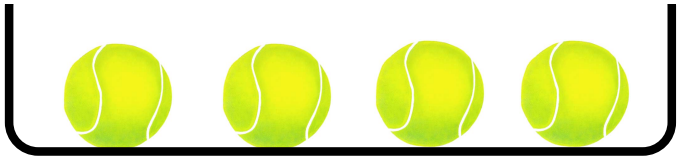
Register 5

Incrementing a Register



Register 5

Incrementing a Register



Register 5

Decrementing a Register

Register 3

Decrementing a Register

Register 3

Decrementing a Register

Register 3

Decrementing a Register

Register 3

Decrementing a Register

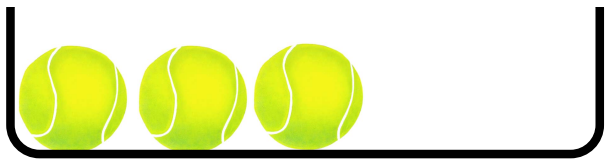
This is our if statement

Register 3

Sample Program:

Add the contents of register 1 to the contents of register 2

Register 1



Register 2

Register 3

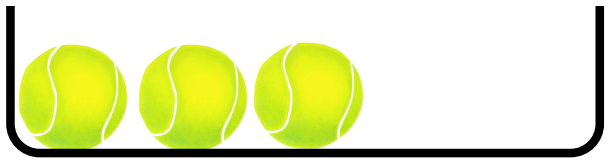
STEP	INSTRUCTION	REGISTER	GO TO STEP	[BRANCH TO STEP]
1.	Deb	1	2	3
2.	Inc	2	1	
3.	End			

Sample Program:

Add the contents of register 1 to the contents of register 2

This register is not used by this program.

Register 1



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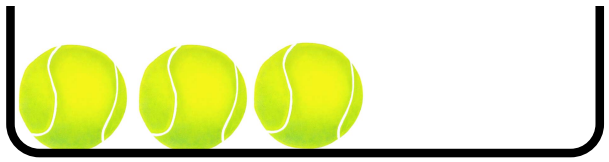

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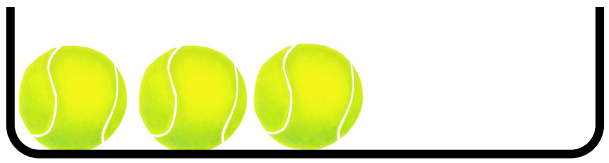

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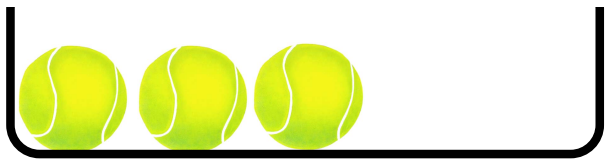

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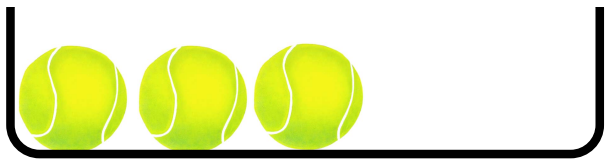

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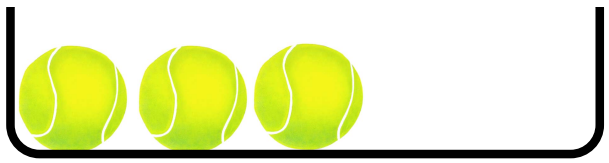

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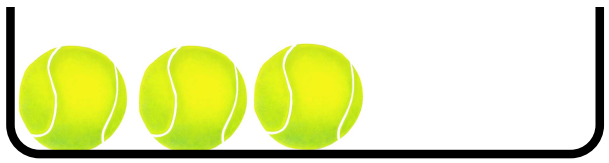

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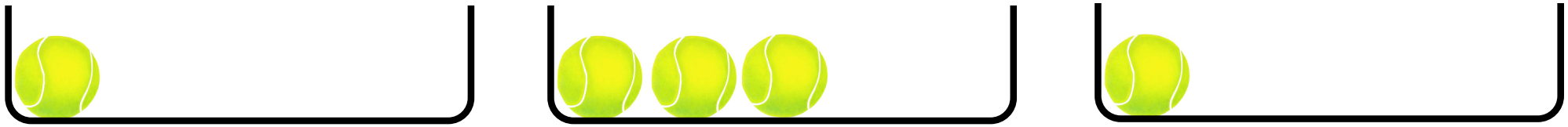

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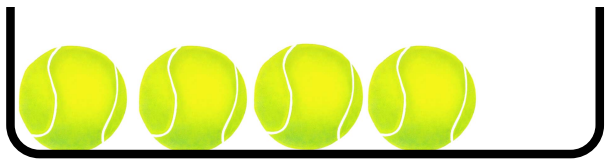

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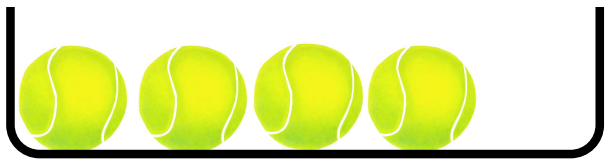

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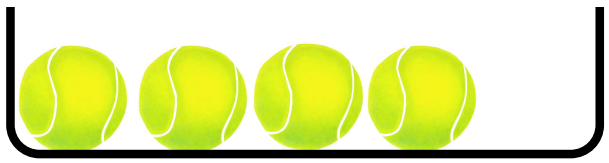

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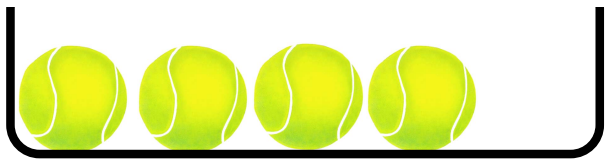

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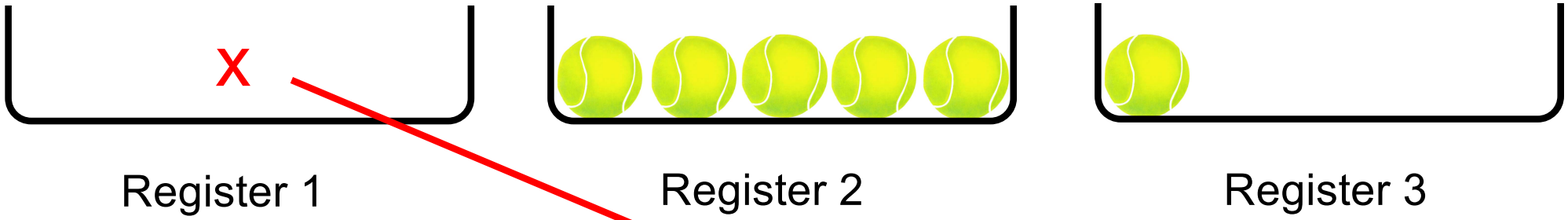

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Register 1 Register 2 Register 3

STEP	INSTRUCTION	REGISTER	GO TO STEP	[BRANCH TO STEP]
1.	Deb	1	2	3
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3.	End			

Same program, different initial conditions

Add the contents of register 1 to the contents of register 2

Register 1

Register 2

Register 3

STEP	INSTRUCTION	REGISTER	GO TO STEP	[BRANCH TO STEP]
1.	Deb	1	2	3
2.	Inc	2	1	
3.	End			

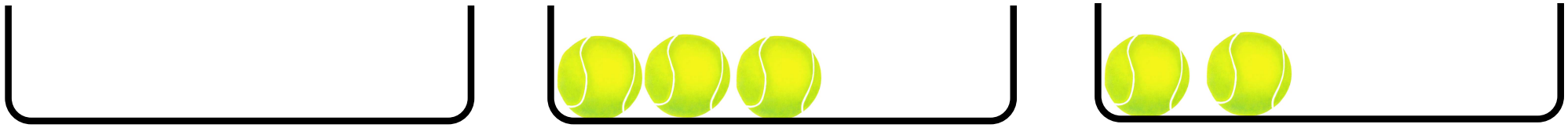
Some Questions

- **Where do the balls that are deleted go?**

- **Where do the balls that are added come from?**

Same program, different initial conditions

Add the contents of register 1 to the contents of register 2



Register 1 Register 2 Register 3

STEP	INSTRUCTION	REGISTER	GO TO STEP	[BRANCH TO STEP]
1.	Deb	1	2	3
2.	Inc	2	1	
3.	End			

Another Program:

Move the contents of register 2 to register 3

Register 1

Register 2

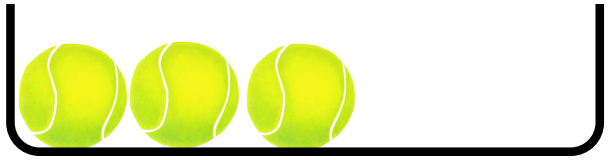
Register 3

STEP	INSTRUCTION	REGISTER	GO TO STEP	[BRANCH TO STEP]
1.	Deb	3	1	2
2.	Deb	2	3	4
3.	Inc	3	2	
4.	End			

Yet Another Program:

Copy the contents of register 1 to register 3

Register 1



Register 2

Register 3

STEP	INSTRUCTION	REGISTER	GO TO STEP	[BRANCH TO STEP]
1.	Deb	3	1	2
2.	Deb	2	2	3
3.	Deb	1	4	6
4.	Inc	3	5	
5.	Inc	2	3	
6.	Deb	2	7	8
7.	Inc	1	6	
8.	End			

RodRego

You can download a register machine emulator from:

http://sites.tufts.edu/rodrego/

It works on both Macs and PCs. It's pretty cool.

This web link is also in the book chapter.

There is also a version that works in a browser:

https://rodrego.it.tufts.edu/

What are the seven secrets?

Secret #1

Competence Without Comprehension - the register machine can do perfect arithmetic without having to comprehend what it is doing.

Secret #2

What a number in a register stands for depends on the program that we have composed.

Secret #3

Since the number in a register machine can stand for anything, this means that the register machine can, in principle, be designed to “notice” anything, to “discriminate" any pattern or feature that can be associated with a number – or a number of numbers.

Secret #4

Since a number can stand for anything, a number can stand for an instruction or an address.

Secret #5

All possible programs can be given a unique number as a name, which can then be treated as a list of instructions to be executed by a Universal machine.

Secret #6

All the improvements in computers since Turing invented his imaginary paper-tape machine are simply ways of making them faster.

Secret #7

There are no more secrets.

What about real computers?

- **Do they really work in this way?**

Questions?

THE END