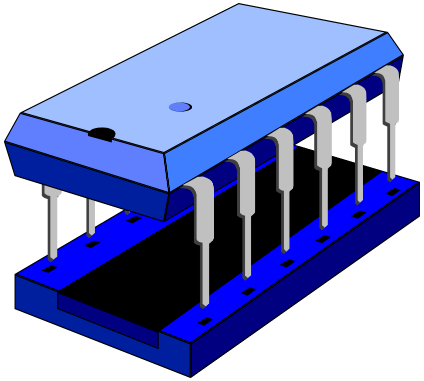
BASIC CIRCUITS AND MEMORY



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Digital Circuits

- Basic Circuits
  - Half Adder
  - Full Adder
  - Latches

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Adders

- A digital circuit that performs **addition** of numbers

- Not only used in arithmetic logic unit(s), but also in other parts of the pro sed to calculate addresses, tabl erations

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- Most common adders operate umbers

Half Adder

- Consider adding two 1-bit binary numbers together:

	0	0	1	1
+				1
				??

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- Input – 2 separate lines

Half Adder

- Consider adding two 1-bit binary numbers together:

	0	0	1	1
+				1
				10

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- Input – 2 separate lines
- Output – two bits – how do we represent this?
  - Use two separate lines (Sum and Carry)

Half Adder

- Can we now draw the circuit?
  - What do we need? – Truth Tables
    - One each for su

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Half Adder

- Recall

	0	0	1	1
+	0	1	0	1
				10

- Truth Table

A	B	A + B		Carry
0	0	0	0	0
0	1	1	1	0
1	0	1	1	0
1	1	2	0	1

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Half Adder

- Selecting Gates

Sum	Carry
0	0
1	
1	
0	1

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XOR	And
0	0
1	0
1	0
0	1

- Hence, we can build the expressions as:
  - Sum = $A \oplus B$
  - Carry = A • B

Half Adder

- Circuit

A

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Sum

B

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A

Carry

B

Is this Correct?

Half Adder

- A more concise and better version ☺

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A

Sum

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B

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Carry

Full Adder

- Half-adders have a major limitation
  - Cannot accept a carry bit from a previous stage → they cannot be chained together to add multi-bit numbers

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- Full-adders can [illegible] ut

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  - Third bit is the carry-in bit

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- Can be cascaded to produce adders of any number of bits by daisy-chaining the carry of one output to the input of the next

Full Adder

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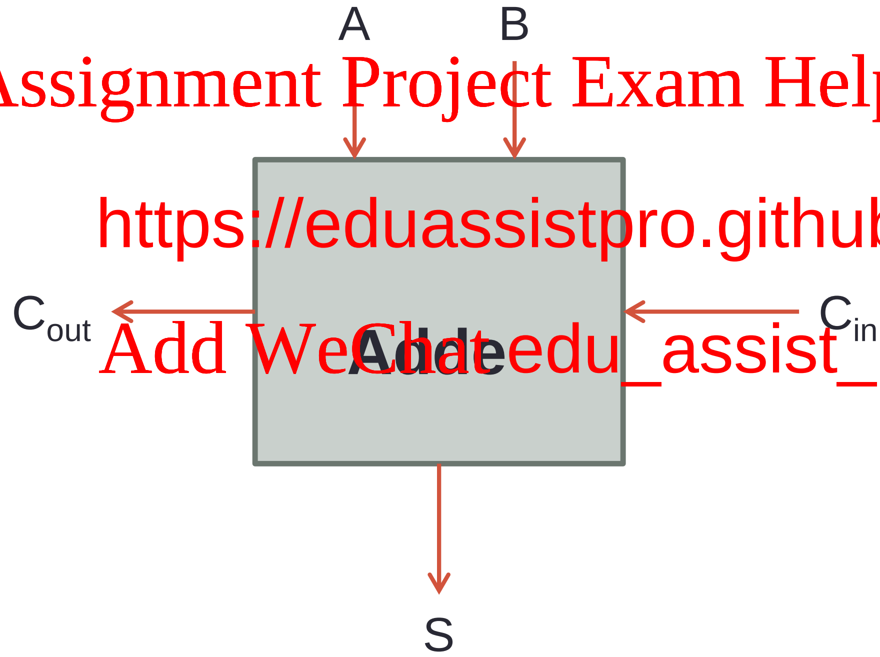
$S = A \oplus B \oplus C_{in}$

$C_{out} = (A \bullet B) + C_{in} \bullet (A \oplus B))$

Full Adder

- Conceptually



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Ripple-Carry Adder

- Consists of several full adders connected in a series so that the carry must propagate through every full adder before the addition is complete

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- Require the lea f all adders, but they are the slowest

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  - Carry-Lookahead Adder (homework)

Ripple-Carry Adder

- The following diagram shows a four-bit adder, which adds the numbers A and B, as well as a carry input, together to produce S and the carry output.

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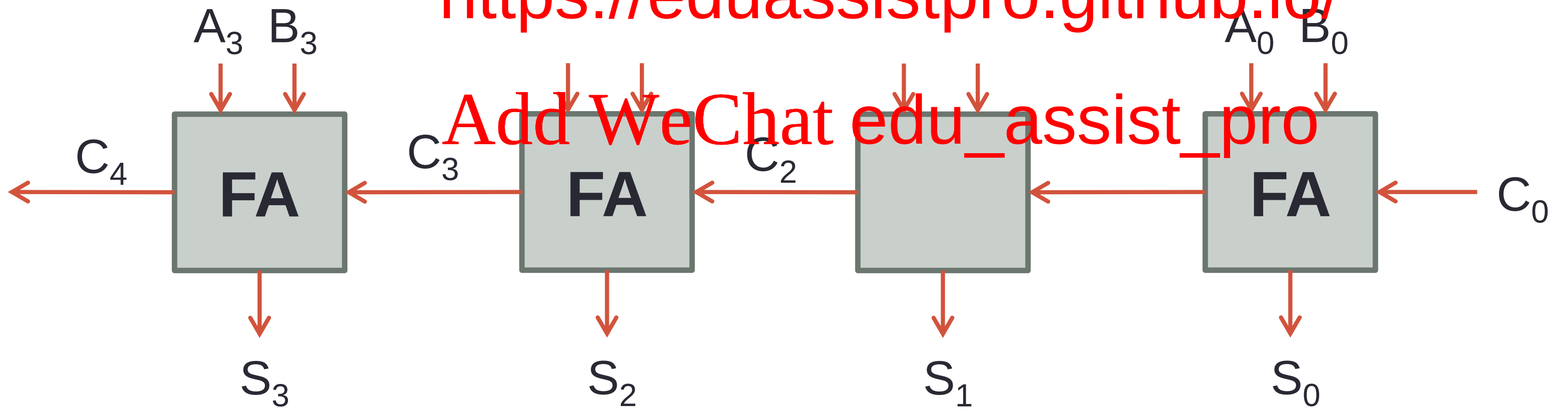

Gates

- Building blocks for combinatorial circuits
  - Output depends only on current Input
- All gates can be [illegible] NOR gates
- What if we would like to store
  - Use a *feedback* mechanism where the output values depend indirectly, on themselves

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Latches

- Building blocks to sequential circuits
- Can be built from gates
- Able to rememb
- Useful web-page
  - http://www.play-hookey.com/digital/sequential/

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Latches

- SR-latch
  - S = Set
  - R = Reset

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Latches

- S = 0, R = 0

0

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0

- Value of Q does not change → value is ‘remembered’
  - Sometimes called the *latch* state

Latches

- S = 1, R = 0

0

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1

- Set the value of Q

Latches

- S = 0, R = 0

0

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0

- Value of Q stays the same – it ‘remembers’ ☺

Latches

- S = 0, R = 1

1

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0

- Reset the value of Q to 0

- S = 1, R = 1 leads to undefined state

Latches

- SR-Latch: Truth table

S	R	Q	Q'
0			
0			1
1	0		
1	1	U	

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Flip-Flops

- Latches are *asynchronous* → output changes very soon after the input changes

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- Most computers
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  - Outputs of all th ... simultaneously to the rhythm of a global *clock signal*

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- A *flip-flop* is a synchronous version of the latch

Memory

- Useful variation on the SR latch circuit is the Data latch, or D latch
- Constructed by using the inverted S input as the R input signal
  - Allows for a singl as input is inverted

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Memory

- Two basic types of memory

- Static RAM (SRAM)
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  - Bit-cell is a latch
  - Fast, not very de rs to implement)
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  - Primarily used in
  - Consumes less power
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- Dynamic RAM (DRAM)
  - Bit-cell is a transistor and capacitor (which leaks information)
    - Storage has to be periodically refreshed
  - Primarily used in main memory
  - Cheaper than SRAM

Memory

- Memories hold binary values
  - Data (e.g. Integers, Reals, Characters)
  - CPU Instructions
  - Memory Addresses ("Pointers" to ctions)
- Contents remain unchanged unless overwritten with a new binary value
  - Some of them *lose* the content when power is turned off (volatile memory)

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Memory – Examples

- CPU, Registers, Caches – L1, L2 [L3]

- Mainboard
  - RAM (Random
  - Caches
  - I/O Registers & Buffers
  - Video-card Memory

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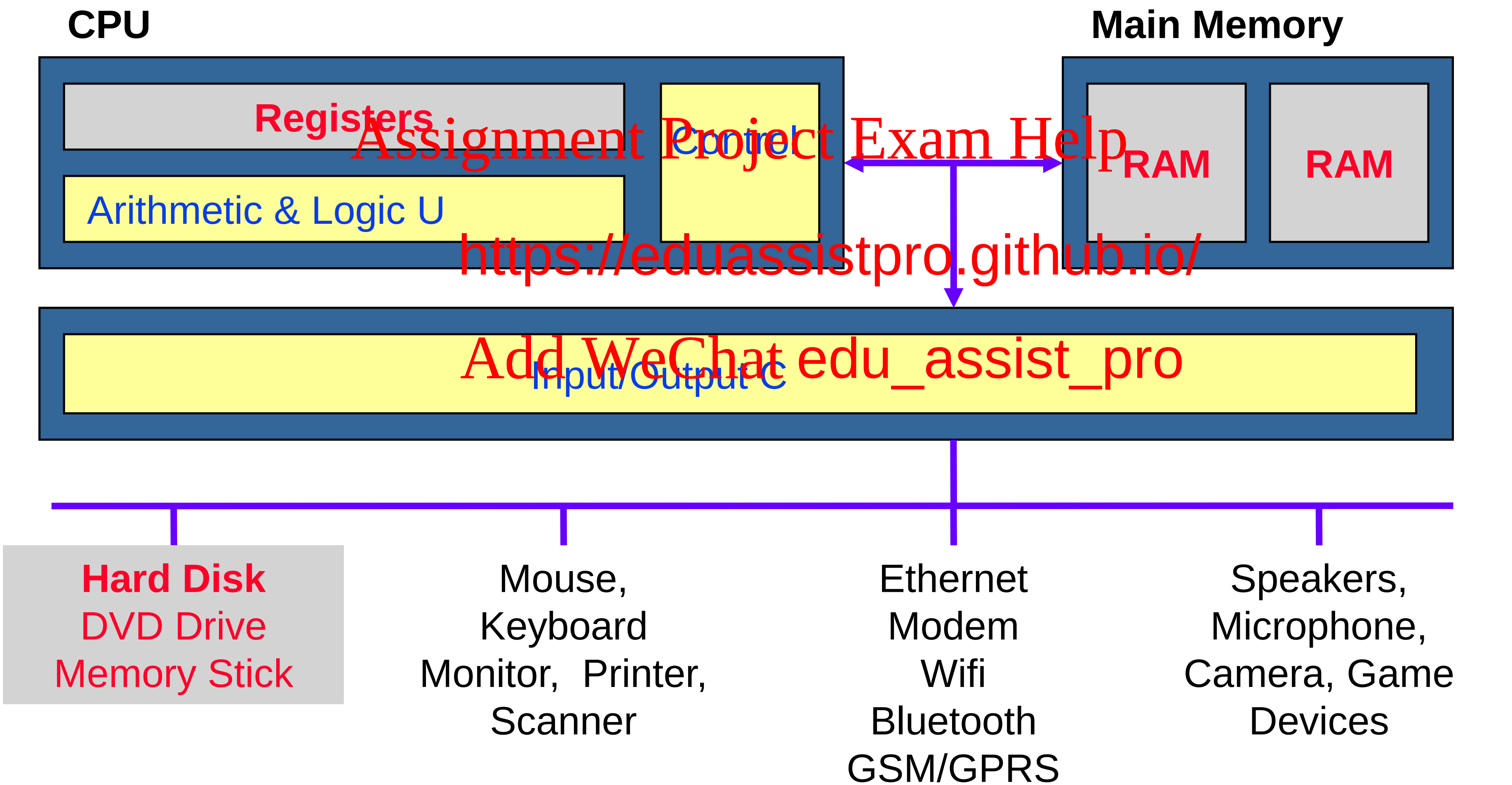
- Storage Devices
  - Hard Disks, CDs, DVDs, Tapes, Memory Sticks, Flashcards

Computer Architecture



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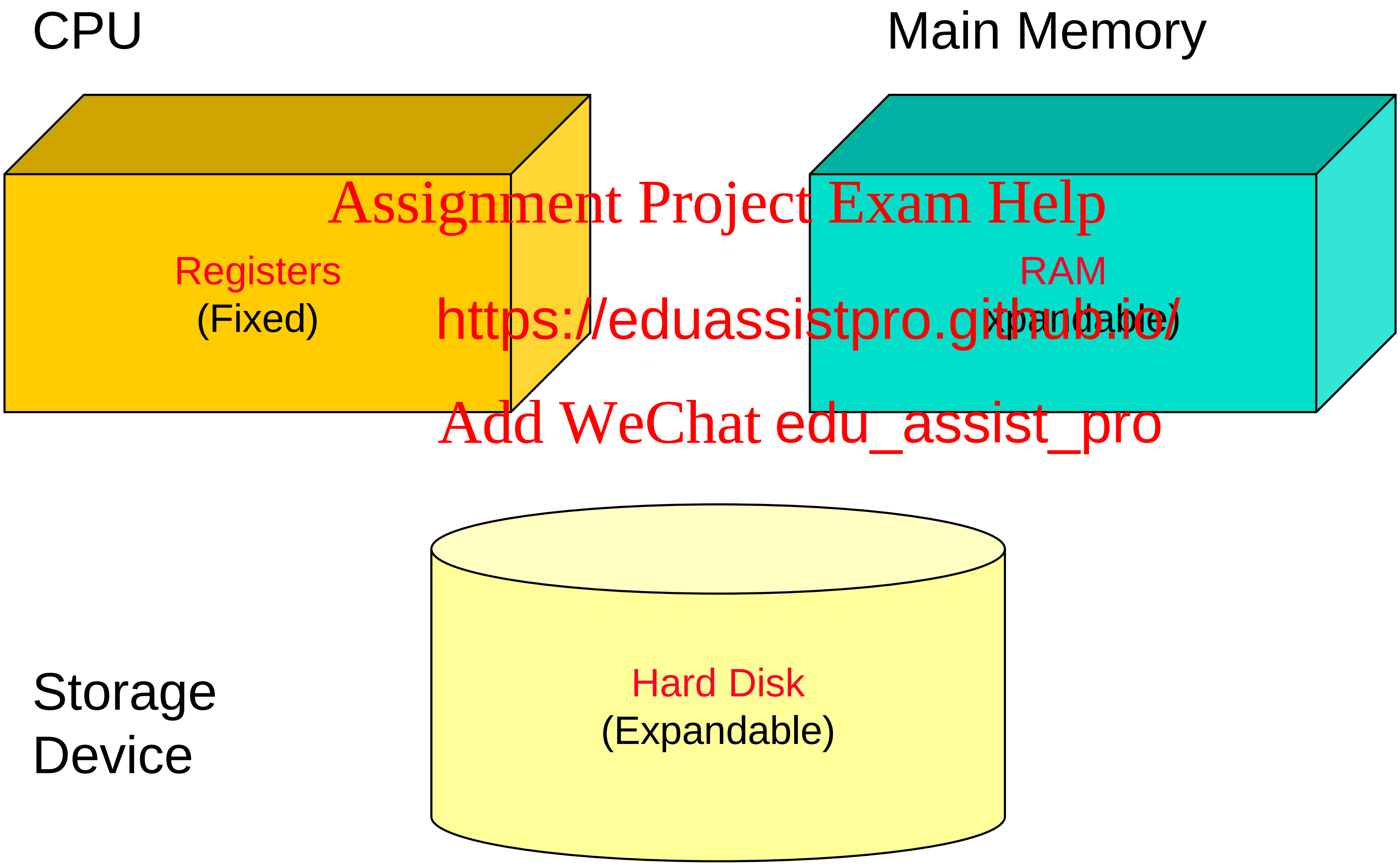
3 Types of Memory



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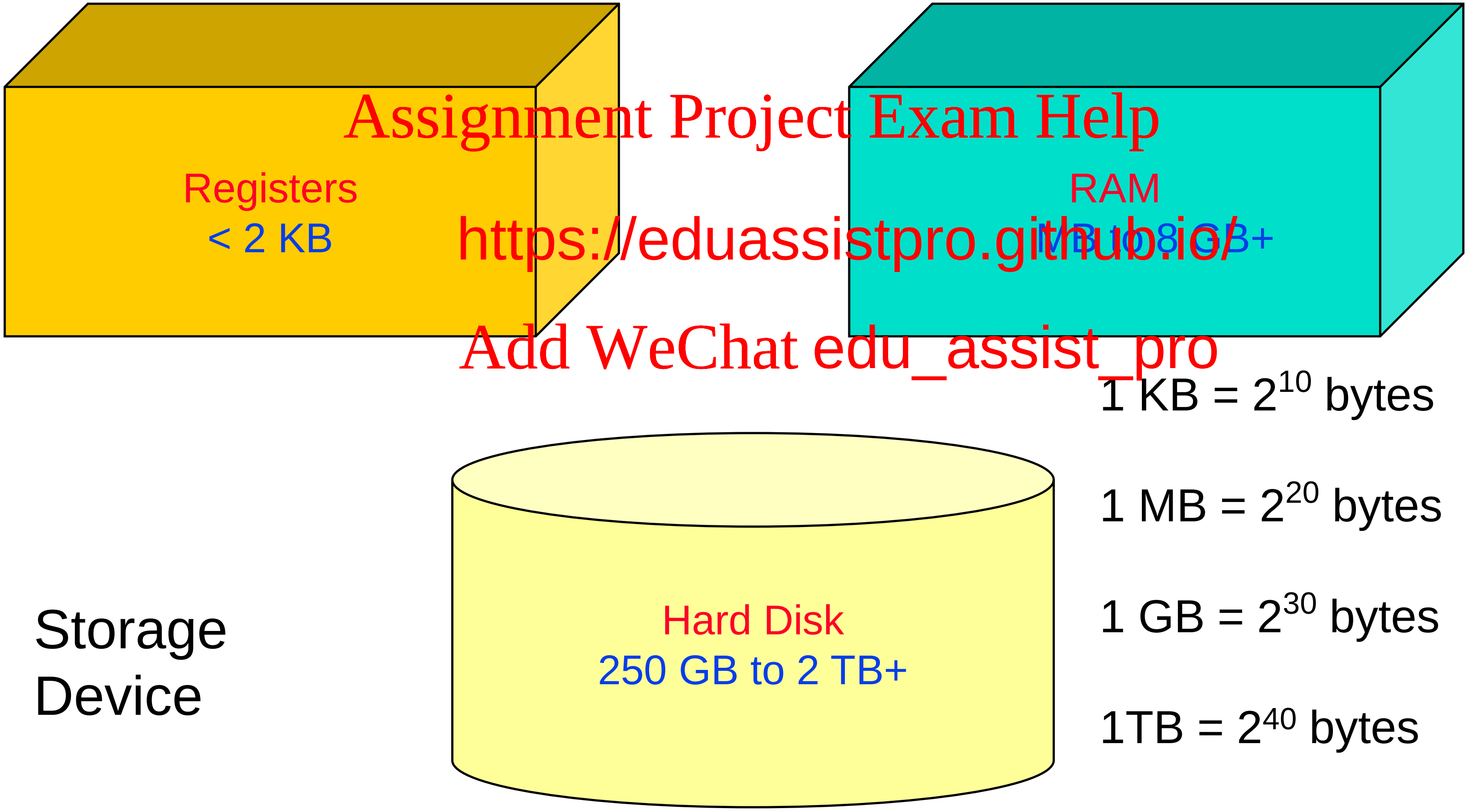
Capacity

CPU

Main Memory



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Storage Device

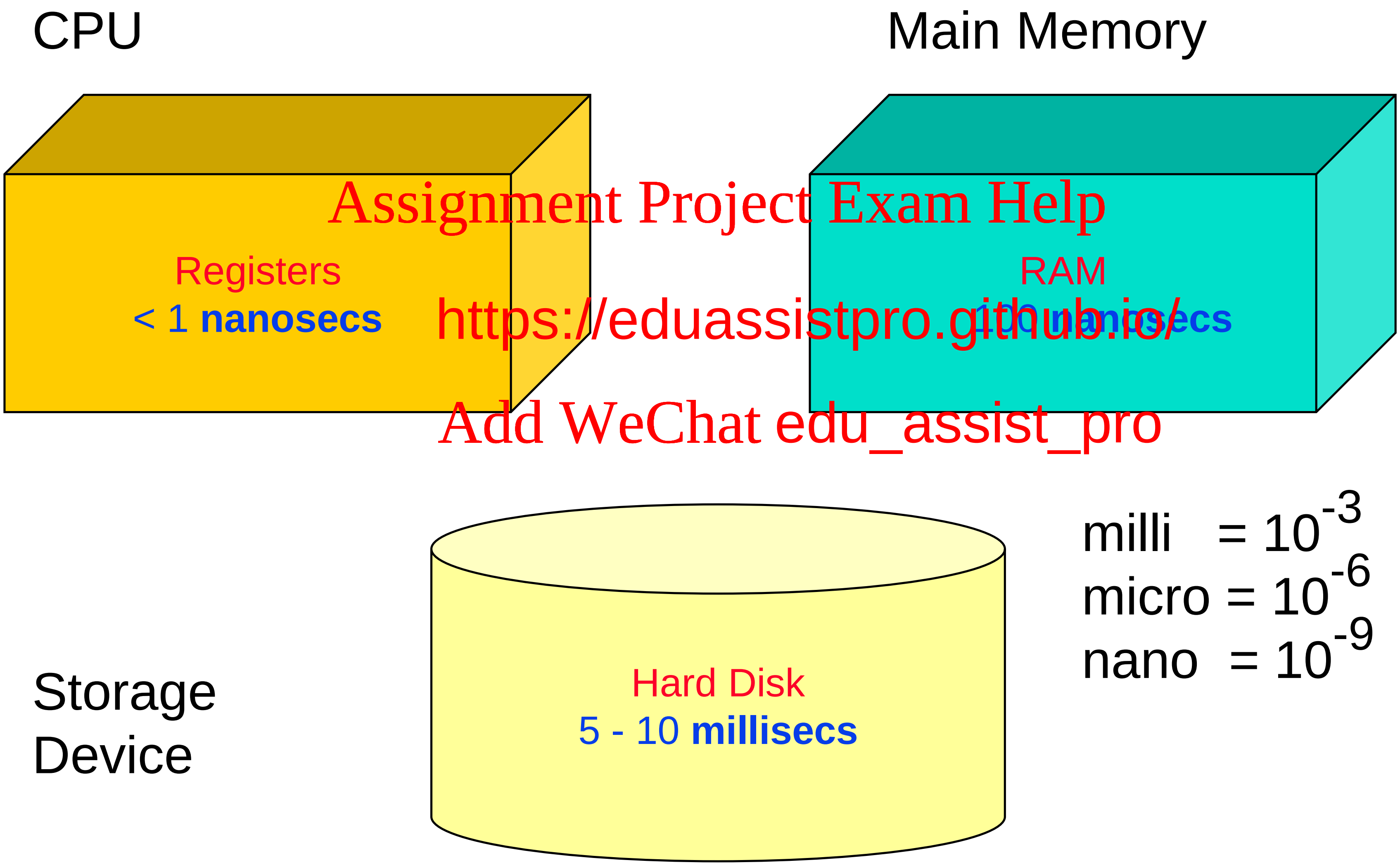
1 KB = 2^{10} bytes

1 MB = 2^{20} bytes

1 GB = 2^{30} bytes

1TB = 2^{40} bytes

Speed (Access Time)



milli $= 10^{-3}$
micro $= 10^{-6}$
nano $= 10^{-9}$

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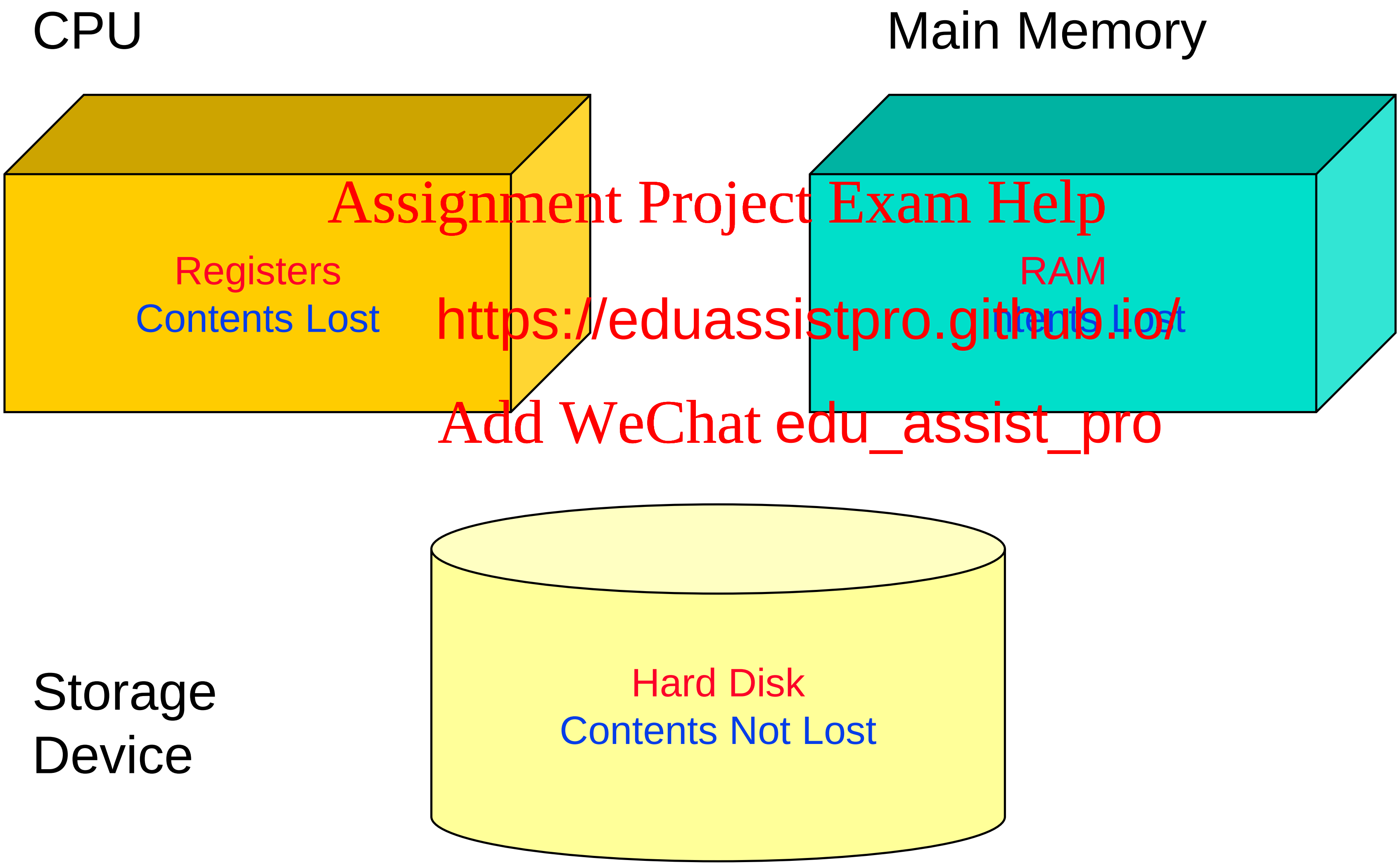
Volatility



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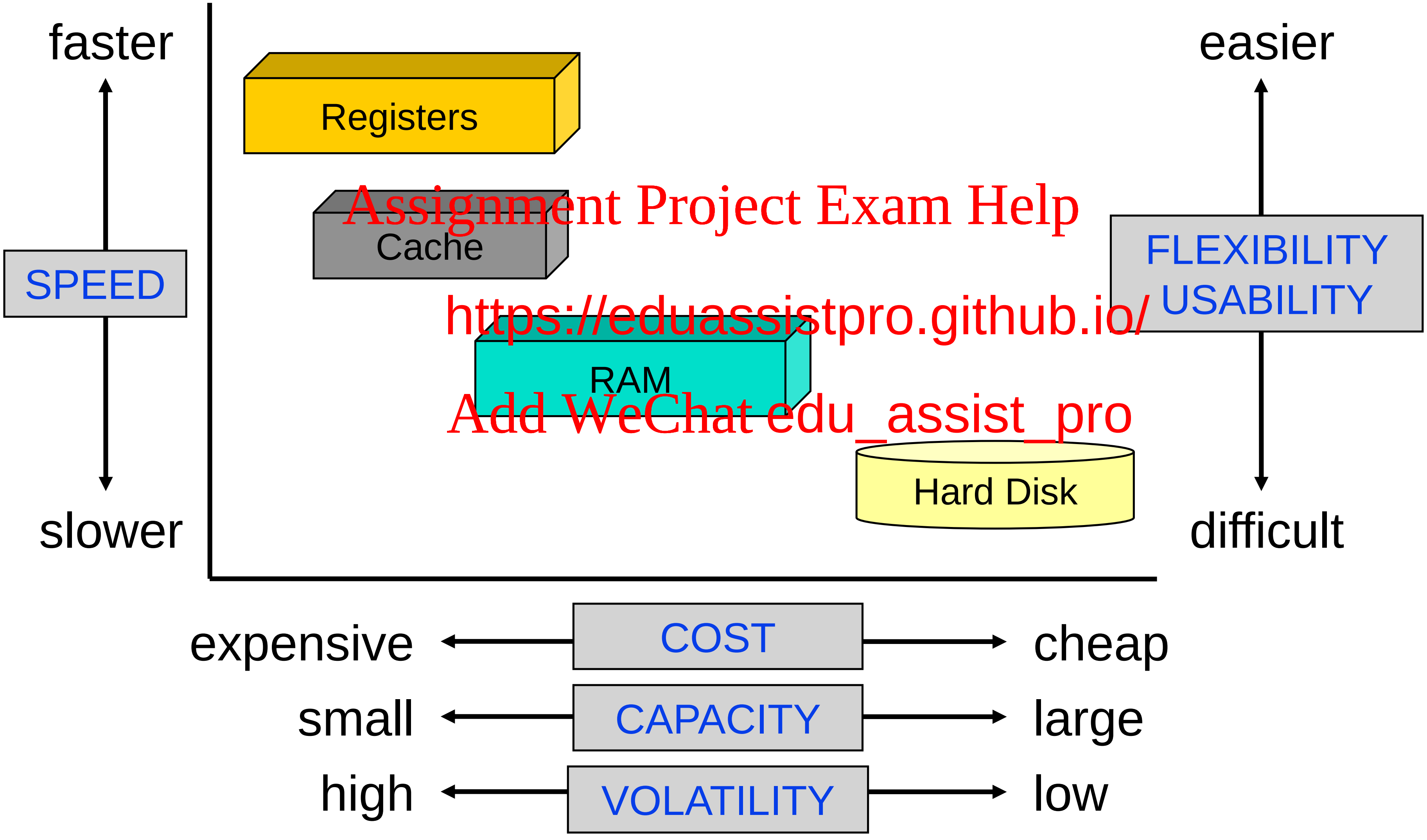
Summary



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