

CSci 127: Introduction to Computer Science



hunter.cuny.edu/csci

Announcements

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Thursday-Saturday, 28-31 November.

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Thursday-Saturday, 28-31 November.
- In response to wrap-up requests, additional challenges today with while loops and binary & hexadecimal numbers.

Today's Topics



- Design Patterns: Searching
- Python Recap
- Machine Language
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic
- Final Exam: Format

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- **Design Patterns: Searching**
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In Pairs or Triples:

Predict what the code will do:

```
def search(nums, locate):
    found = False
    i = 0
    while not found and i < len(nums):
        print(nums[i])
        if locate == nums[i]:
            found = True
        else:
            i = i+1
    return(found)

nums= [1,4,10,6,5,42,9,8,12]
if search(nums,6):
    print('Found it! 6 is in the list!')
else:
    print('Did not find 6 in the list.')|
```

Python Tutor

```
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```

(Demo with pythonTutor)

Design Pattern: Linear Search

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- Look at each item, one-by-one.

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- Example of **linear search**.
- Start at the beginning of the list.
- Look at each item, one-by-one.
- Stopping, when found, or the end of list is reached.

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- **Python Recap**
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- Machine Language: Jumps & Loops
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Python & Circuits Review: 10 Weeks in 10 Minutes



A whirlwind tour of the semester, so far...

Week 1: print(), loops, comments, & turtles

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- Introduced comments & print():

```
#Name: Thomas Hunter
```

← These lines are comments

```
#Date: September 1, 2017
```

← (for us, not computer to read)

```
#This program prints: Hello, World!
```

← (this one also)

```
print("Hello, World!")
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← Prints the string "Hello, World!" to the screen

Week 1: print(), loops, comments, & turtles

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- As well as definite loops & the turtle package:

The screenshot shows a Python code editor with a file named 'main.py' open. The code is as follows:

```
1 #A program that demonstrates turtles stamping
2
3 import turtle
4
5 taylor = turtle.Turtle()
6 taylor.color("purple")
7 taylor.shape("turtle")
8
9 for i in range(6):
10     taylor.forward(100)
11     taylor.stamp()
12     taylor.left(60)
```

To the right of the code editor is a 'Result' window displaying a purple hexagon drawn by the turtle. The turtle has stamped a purple star at each vertex of the hexagon.

Week 2: variables, data types, more on loops & range()

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 - ▶ **class variables**: for complex objects, like turtles.

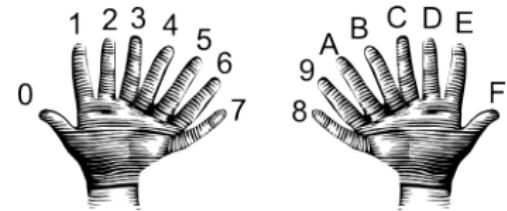
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 - ▶ **class variables**: for complex objects, like turtles.
- More on loops & ranges:

```
1 #Predict what will be printed:  
2  
3 for num in [2,4,6,8,10]:  
4     print(num)  
5  
6 sum = 0  
7 for x in range(0,12,2):  
8     print(x)  
9     sum = sum + x  
10  
11 print(x)  
12  
13 for c in "ABCD":  
14     print(c)
```

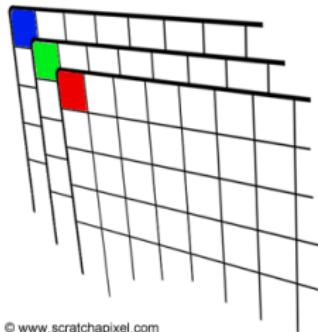
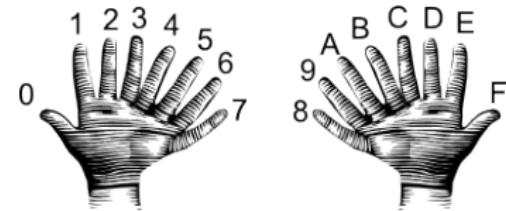
Week 3: colors, hex, slices, numpy & images

Color Name	HEX	Color
Black	#000000	
Navy	#000080	
DarkBlue	#00008B	
MediumBlue	#0000CD	
Blue	#0000FF	



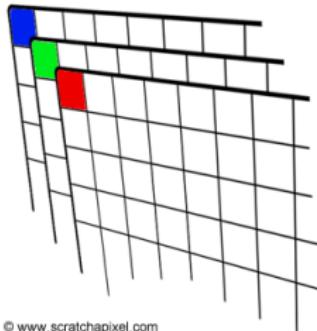
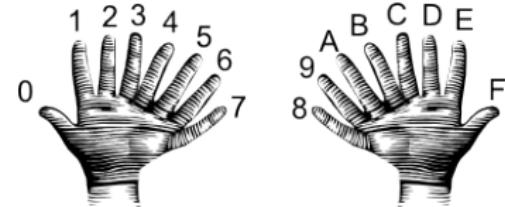
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```
>>> a[0:3:5]  
array([3,4])
```

```
>>> a[4:,4:]  
array([[44, 45],  
       [54, 55]])
```

```
>>> a[:,2]  
array([2,12,22,32,42,52])
```

```
>>> a[2::2,:,:2]  
array([[20,22,24],  
       [40,42,44]])
```

0	1	2	3	4	5
10	11	12	13	14	15
20	21	22	23	24	25
30	31	32	33	34	35
40	41	42	43	44	45
50	51	52	53	54	55

Week 4: design problem (cropping images) & decisions



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- Next: write pseudocode.
 - ① Import numpy and pyplot.
 - ② Ask user for file names and dimensions for cropping.
 - ③ Save input file to an array.
 - ④ Copy the cropped portion to a new array.
 - ⑤ Save the new array to the output file.

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 - ④ Copy the cropped portion to a new array.
 - ⑤ Save the new array to the output file.
- Next: translate to Python.

Week 4: design problem (cropping images) & decisions

```
yearBorn = int(input('Enter year born: '))
if yearBorn < 1946:
    print("Greatest Generation")
elif yearBorn <= 1964:
    print("Baby Boomer")
elif yearBorn <= 1984:
    print("Generation X")
elif yearBorn <= 2004:
    print("Millennial")
else:
    print("TBD")

x = int(input('Enter number: '))
if x % 2 == 0:
    print('Even number')
else:
    print('Odd number')
```

Week 5: logical operators, truth tables & logical circuits

```
origin = "Indian Ocean"
winds = 100
if (winds > 74):
    print("Major storm, called a ", end="")
    if origin == "Indian Ocean" or origin == "South Pacific":
        print("cyclone.")
    elif origin == "North Pacific":
        print("typhoon.")
    else:
        print("hurricane.")

visibility = 0.2
winds = 40
conditions = "blowing snow"
if (winds > 35) and (visibility < 0.25) and \
   (conditions == "blowing snow" or conditions == "heavy snow"):
    print("Blizzard!")
```

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```

in1	and	in2	returns:
False	and	False	False
False	and	True	False
True	and	False	False
True	and	True	True



Week 6: structured data, pandas, & more design

Source: https://en.wikipedia.org/wiki/Demographics_of_New_York_City,
All population figures are consistent with present-day boundaries.....
First census after the consolidation of the five boroughs.....

.....
Year,Manhattan,Brooklyn,Queens,Bronx,Staten Island,Total
1890,1,230,203,727,784,2,230
1891,2,238,3,462,,2,847,28,423
1790,33131,4549,6159,1781,3827,49447
1800,60515,5740,6442,1755,4543,75955
1810,61311,5854,6348,1755,4543,75934
1820,123704,11187,8246,2792,6135,152056
1830,202589,20535,9049,3023,7082,242278
1840,312110,12013,14049,5346,10965,391114
1850,355411,12850,14895,5346,10965,415115
1860,513469,279122,32903,23593,25492,174777
1870,942292,419921,45468,37393,33029,1479103
1880,1164473,59943,5653,51980,33021,1911801
1890,1367711,66582,51583,48128,31861,2051134
1900,185093,116582,152999,200567,67921,2437202
1910,2233142,1634351,264041,430980,8569,4766803
1920,2211103,2018354,44603,44603,73201,11651,50048
1930,1867112,1579128,230354,230354,58321,4930446
1940,1889924,2498285,1297634,1394711,374441,7454995
1950,1960101,2738175,1550849,1451277,191555,7991957
1960,1690101,2303519,1890591,1451277,191555,7981984
1970,1539231,2460705,1471071,1471071,135443,7981984
1980,1426285,2230936,1891325,1168972,352121,7071639
1990,1487536,2300664,1951598,1203789,378977,7322564
2000,1537195,2485326,2229379,1332450,419782,8080879
2010,1583873,2504705,2216722,1385108,4475158,8175133
2015,1444518,2646733,2339150,1454446,474558,8059405

nycHistPop.csv

In Lab 6

Week 6: structured data, pandas, & more design

```
import matplotlib.pyplot as plt  
import pandas as pd
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Year,Manhattan,Brooklyn,Queens,Bronx,Staten Island,Total
1890,4937,2037,,727,7881
1871,21843,3623,,2847,28423
1790,33131,4549,6159,1781,3827,49447
1800,60515,5740,6442,1755,4543,75955
1810,63545,5740,6442,1755,4543,75934
1820,123704,11187,8246,2792,6135,152056
1830,202589,20535,9049,3023,7082,242278
1840,312110,18013,14034,5346,10965,391114
1850,35549,12891,18951,2894,10965,391115
1860,813469,279122,32903,23593,25492,174777
1870,942292,419921,45468,37393,33029,1479103
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1890,1367711,66411,6348,51980,33029,1911804
1900,185093,116582,152999,200567,67621,2437202
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1920,2210103,2018354,446071,446071,732013,1165115,500488
1930,1667111,1796128,1796128,1796128,1796128,4930446
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nycHistPop.csv

In Lab 6

Week 6: structured data, pandas, & more design

```
import matplotlib.pyplot as plt  
import pandas as pd
```

```
pop = pd.read_csv('nycHistPop.csv', skiprows=5)
```

```
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All population figures are consistent with present-day boundaries.....  
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.....  
Year,Manhattan,Brooklyn,Queens,Bronx,Staten Island,Total  
1690,4937,2037,727,788,102  
1771,21843,3623,2847,28423  
1790,33131,4549,6159,1781,3827,49447  
1800,60515,5740,6442,1755,4543,75955  
1810,68000,62000,68000,17000,45000,93734  
1820,123704,11187,8246,2792,6135,152056  
1830,202589,20535,9049,3023,7082,242278  
1840,312110,18013,14000,5346,10965,391114  
1850,355491,21800,18500,5800,11000,500115  
1860,613469,279122,32903,23593,25492,174777  
1870,942292,419921,45468,37393,33029,1479103  
1880,1164473,59940,5653,51980,33091,1911801  
1890,1367711,70000,65000,58000,33000,2150004  
1900,1850593,116582,152999,200567,67621,2437202  
1910,2233142,1634351,2841,430980,8569,476683  
1920,22161103,2018354,44600,72021,11650,50048  
1930,18671128,1790128,1790128,1790128,1790128,4930446  
1940,1889924,2698285,1297634,1394711,174441,7454995  
1950,1960101,2738175,1550949,1451277,191555,7991957  
1960,1690000,2319319,1890000,1890000,1890000,781984  
1970,1539231,2465701,2465701,2465701,2465443,798460  
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Year,Population  
1690,203,2037,...,727,7181  
1771,21843,28232,...,2847,28423  
1790,33131,4549,6159,1781,3827,49447  
1800,60515,5740,6442,1755,4543,75955  
1810,70000,6350,7000,1800,5300,89734  
1820,123704,11187,8246,2792,6135,152056  
1830,20589,20535,9049,3023,7082,242278  
1840,31510,21013,14000,5346,10965,391114  
1850,35549,21890,18895,5346,10965,391115  
1860,813469,279122,32903,23593,25492,174777  
1870,942292,419921,45468,37393,33029,1479103  
1880,1164473,59943,5653,51980,33091,1911801  
1890,1385700,72000,68000,58000,33091,1911804  
1900,185093,116582,152999,200567,67621,2437202  
1910,223342,1634351,2841,430980,8569,476683  
1920,2246103,2018354,44601,44601,73201,11671,50048  
1930,2667128,2079128,2079128,2079128,5874,4930446  
1940,1889924,2498285,1297634,1394711,174441,7454995  
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1960,1690000,2319319,1890000,1890000,1890000,781984  
1970,1539231,2465701,2465701,2465701,235443,796462  
1980,1426285,2230936,1891325,1168972,352121,7071639  
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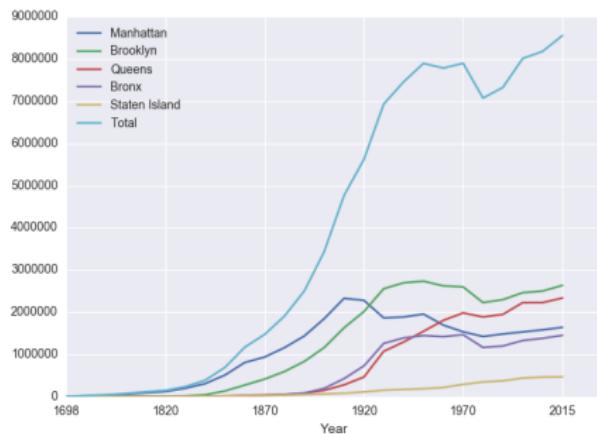
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Year,Borough,Population  
1699,Manhattan, Brooklyn, Queens, Bronx, Staten Island, Total  
1771,21843,36231,2847,28423  
1790,33131,4549,6159,1781,3827,49447  
1800,60515,5740,6442,1755,4543,75935  
1810,67531,6031,6811,1801,4931,89734  
1820,123704,11187,8246,2792,6135,152056  
1830,202889,20535,9049,3023,7082,242278  
1840,312110,18013,14031,5348,10965,391114  
1850,355441,21800,18851,5831,11515,45115  
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1880,1164473,59943,5653,51980,33051,1911801  
1890,1380711,71011,6301,58100,35051,2151134  
1900,1850993,116582,152999,200567,67921,2437202  
1910,233142,1634351,2841,430980,8569,476683  
1920,2210103,2018354,44601,46701,73201,11651,50048  
1930,2667103,2186128,45254,45254,5582,4930446  
1940,1889924,2698285,1297634,1394711,174441,7454995  
1950,1960101,2738175,1550849,1451277,191555,7091957  
1960,1696101,2738175,1809049,1451277,191555,7091984  
1970,1539231,2465701,1472701,1235443,7091984  
1980,1426285,2230936,1891325,1168972,352121,7071639  
1990,1487536,2300664,1951598,1320789,378977,7322564  
2000,1537195,2485326,2229379,1332450,419728,8080879  
2010,1583873,2504705,2216722,1385108,419728,8175133  
2015,1444518,2636733,2339150,1459446,474558,8059405
```

nycHistPop.csv

In Lab 6



Week 7: functions

- Functions are a way to break code into pieces, that can be easily reused.

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#Name: your name here
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#This program, uses functions,
#      says hello to the world!

def main():
    print("Hello, World!")

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Week 8: function parameters, github

- Functions can have **input parameters**.

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def totalWithTax(food,tip):  
    total = 0  
    tax = 0.0875  
    total = food + food * tax  
    total = total + tip  
    return(total)  
  
lunch = float(input('Enter lunch total: '))  
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Week 9: top-down design, folium, loops, and random()



```
def main():
    dataF = getData()
    latColName, lonColName = getColumnNames()
    lat, lon = getLocale()
    cityMap = folium.Map(location = [lat,lon], tiles = 'cartodbpositron',zoom_start=11)
    dotAllPoints(cityMap,dataF,latColName,lonColName)
    markAndFindClosest(cityMap,dataF,latColName,lonColName,lat,lon)
    writeMap(cityMap)
```

Week 10: more on loops, max design pattern, random()

```
dist = int(input('Enter distance: '))
while dist < 0:
    print('Distances cannot be negative.')
    dist = int(input('Enter distance: '))

print('The distance entered is', dist)
```

- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.

```
import turtle
import random

trey = turtle.Turtle()
trey.speed(10)

for i in range(100):
    trey.forward(10)
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- Python's built-in random package has useful methods for generating random whole numbers and real numbers.
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`import random`.
- The max design pattern provides a template for finding maximum value from a list.

Python & Circuits Review: 10 Weeks in 10 Minutes



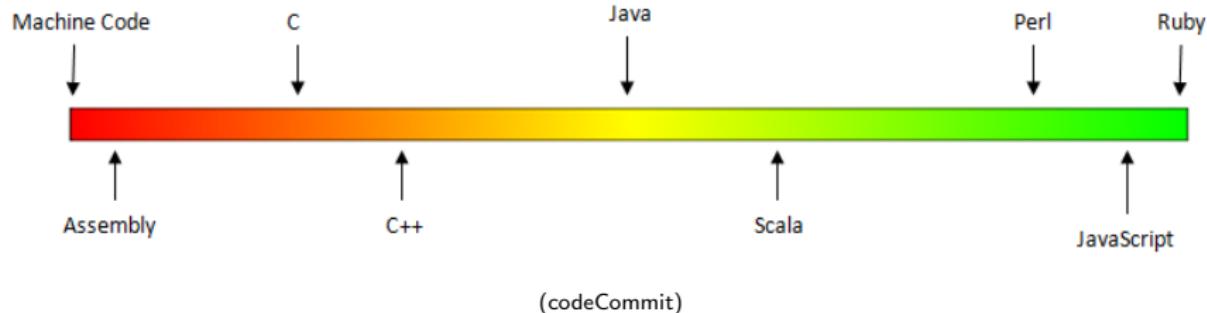
- Input/Output (I/O): `input()` and `print()`; pandas for CSV files
- Types:
 - ▶ Primitive: `int`, `float`, `bool`, `string`;
 - ▶ Container: lists (but not dictionaries/hashes or tuples)
- Objects: turtles (used but did not design our own)
- Loops: definite & indefinite
- Conditionals: `if-elif-else`
- Logical Expressions & Circuits
- Functions: parameters & returns
- Packages:
 - ▶ Built-in: `turtle`, `math`, `random`
 - ▶ Popular: `numpy`, `matplotlib`, `pandas`, `folium`

Today's Topics



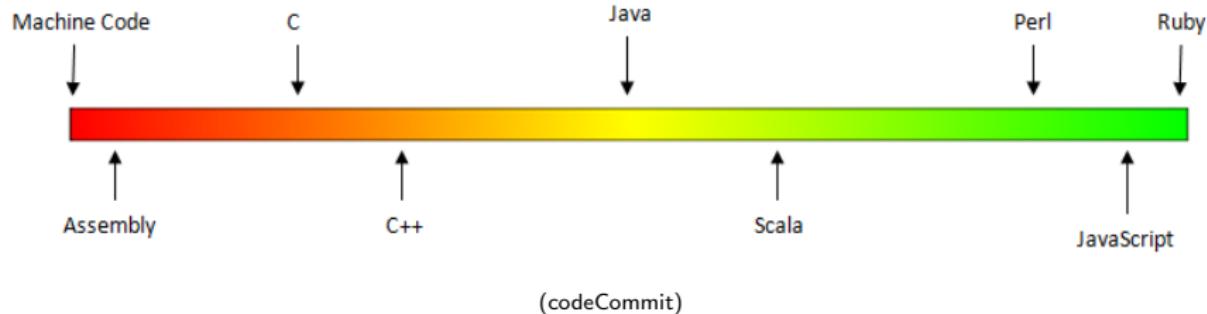
- Design Patterns: Searching
- Python Recap
- **Machine Language**
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic
- Final Exam: Format

Low-Level vs. High-Level Languages



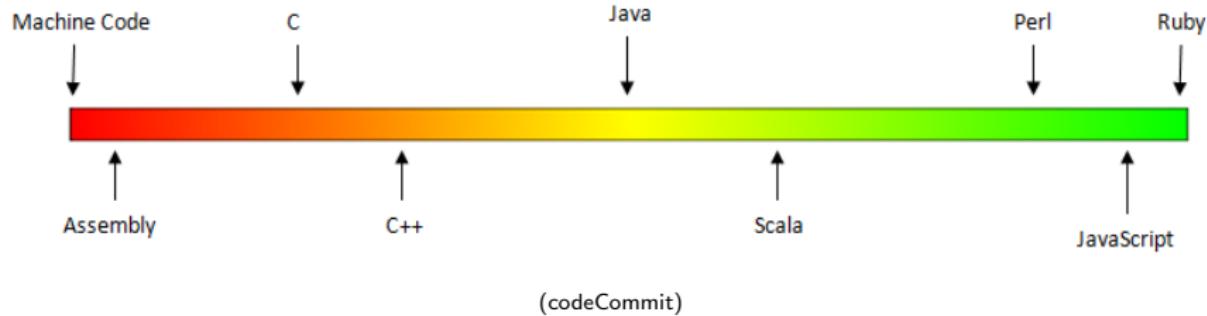
- Can view programming languages on a continuum.

Low-Level vs. High-Level Languages



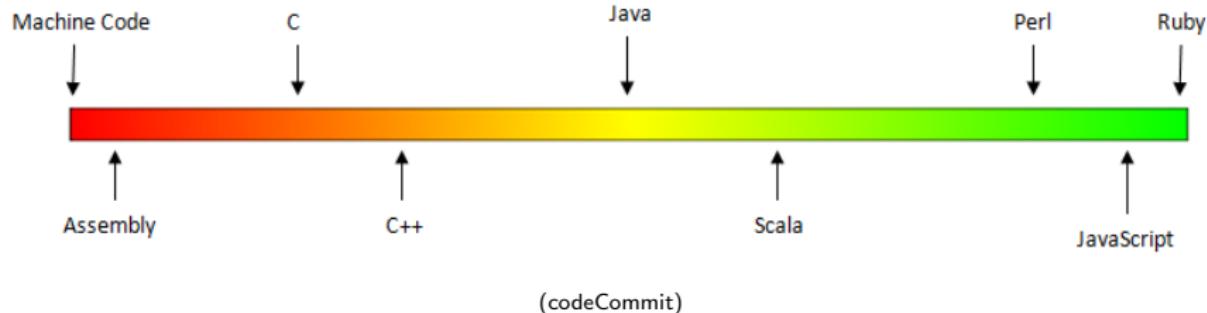
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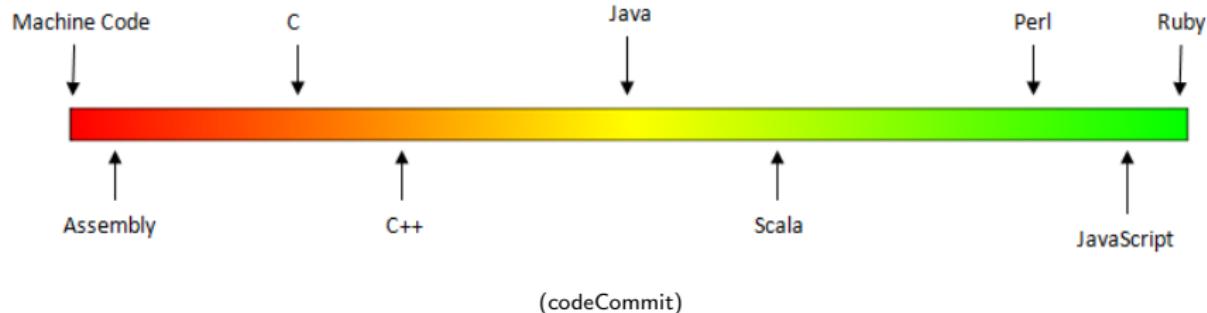
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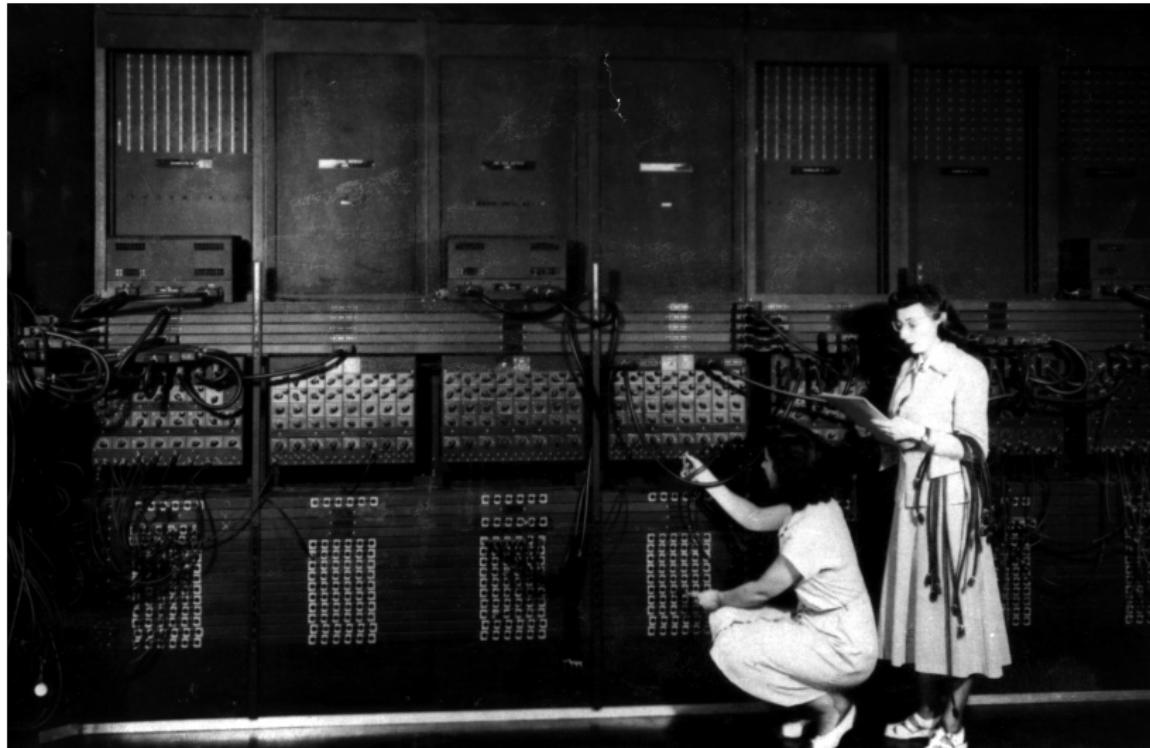
- Can view programming languages on a continuum.
- Those that directly access machine instructions & memory and have little abstraction are **low-level languages** (e.g. machine language, assembly language).
- Those that have strong abstraction (allow programming paradigms independent of the machine details, such as complex variables, functions and looping that do not translate directly into machine code) are called **high-level languages**.

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- Those that have strong abstraction (allow programming paradigms independent of the machine details, such as complex variables, functions and looping that do not translate directly into machine code) are called **high-level languages**.
- Some languages, like C, are in between— allowing both low level access and high level data structures.

Machine Language



(Ruth Gordon & Ester Gerston programming the ENIAC, UPenn)

Machine Language

```
I FOX 12:01a 23- 1
A 002000 C2 30      REP #$30
A 002002 18          CLC
A 002003 F8          SED
A 002004 A9 34 12    LDA #$1234
A 002007 69 21 43    ADC #$4321
A 00200A 8F 03 7F 01 STA $017F03
A 00200E D8          CLD
A 00200F E2 30      SEP #$30
A 002011 00          BRK
A 2012

r
PB PC  NUMxDIZC .A .X .Y SP DP DB
; 00 E012 00110000 0000 0000 0002 CFFF 0000 00
g 2000

BREAK

PB PC  NUMxDIZC .A .X .Y SP DP DB
; 00 2013 00110000 5555 0000 0002 CFFF 0000 00
m 7f03 7f03
>007F03 55 55 00 00 00 00 00 00 00 00 00 00 00 00 00:UU .....
```

(wiki)

Machine Language

- We will be writing programs in a simplified machine language, WeMIPS.

(wiki)

Machine Language

(wiki)

- We will be writing programs in a simplified machine language, WeMIPS.
 - It is based on a reduced instruction set computer (RISC) design, originally developed by the MIPS Computer Systems.

Machine Language

```

A 002000 C2 3B REP #3B
A 002002 7F CLC
A 002003 FB SED
A 002004 34 32 #1234
A 002007 69 21 43 ADC #43
A 002008 69 03 7F STA #7F
A 00200E D9 CLD
A 00200F E2 3B SEP #3B
A 002011 90 BHK
A 002012

```

F

```

PB PC Mm0:012C A X Y SP DP IB
; 00 2013 00100000 0000 0000 0002 CFFF 0000 00
$ 2000

BREAK

PB PC Mm0:012C A X Y SP DP IB
; 00 2013 00100000 0550 0000 0002 CFFF 0000 00
$ 7193 7193

Mm0:012C 55 55 00 00 00 00 00 00 00 00 00 00 00 00 00 00

```

(wiki)

- We will be writing programs in a simplified machine language, WeMIPS.
 - It is based on a reduced instruction set computer (RISC) design, originally developed by the MIPS Computer Systems.
 - Due to its small set of commands, processors can be designed to run those commands very efficiently.

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(wiki)

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 - It is based on a reduced instruction set computer (RISC) design, originally developed by the MIPS Computer Systems.
 - Due to its small set of commands, processors can be designed to run those commands very efficiently.
 - More in future architecture classes....

"Hello World!" in Simplified Machine Language

Line: 3 Go!

Show/Hide Demos

User Guide | Unit Tests | Docs

Addition Doubler Stav Looper Stack Test Hello World

Code Gen Save String Interactive Binary2 Decimal Decimal2 Binary

Debug

```
1 # Store 'Hello world!' at the top of the stack
2 ADDI $sp, $sp, -13
3 ADDI $t0, $zero, 72 # H
4 SB $t0, 0($sp)
5 ADDI $t0, $zero, 101 # e
6 SB $t0, 1($sp)
7 ADDI $t0, $zero, 108 # l
8 SB $t0, 2($sp)
9 ADDI $t0, $zero, 108 # i
10 SB $t0, 3($sp)
11 ADDI $t0, $zero, 111 # o
12 SB $t0, 4($sp)
13 ADDI $t0, $zero, 32 # (space)
14 SB $t0, 5($sp)
15 ADDI $t0, $zero, 119 # w
16 SB $t0, 6($sp)
17 ADDI $t0, $zero, 111 # o
18 SB $t0, 7($sp)
19 ADDI $t0, $zero, 114 # r
20 SB $t0, 8($sp)
21 ADDI $t0, $zero, 108 # l
22 SB $t0, 9($sp)
23 ADDI $t0, $zero, 100 # d
24 SB $t0, 10($sp)
25 ADDI $t0, $zero, 33 # !
26 SB $t0, 11($sp)
27 ADDI $t0, $zero, 0 # (null)
28 SB $t0, 12($sp)
29
30 ADDI $v0, $zero, 4 # 4 is for print string
31 ADDI $a0, $sp, 0
32 syscall           # print to the log
```

Step	Run	<input checked="" type="checkbox"/> Enable auto switching			
S	T	A	V	Stack	Log
s0:				10	
s1:				9	
s2:				9	
s3:				22	
s4:				696	
s5:				976	
s6:				927	
s7:				418	

(WeMIPS)



WeMIPS

(Demo with WeMIPS)

MIPS Commands

- **Registers:** locations for storing information that can be quickly accessed.

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MIPS Commands

- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...
 - **R Instructions:** Commands that use data in the registers:
add \$s1, \$s2, \$s3

MIPS Commands

The screenshot shows a window titled "StackFrame Demo". At the top, there are tabs for "User", "3", "64", "ShowFrame Demo", "User Guide", "Unit Tests", and "Doc". Below the tabs are buttons for "Addition Counter", "Stack", "Loop", "Stack Test", "Hello World", "Code Gen Save String", "Interactive", "Binary Decimal", "Decimal Binary", and "Debug". The main area contains assembly code and a register dump.

Assembly Code:

```
1 # Shows "Hello world" at the top of the stack
2 .text
3 .globl _start
4 _start:
5    addi   $s0,$zero,101 # $s0 = 101
6    addi   $s1,$zero,102 # $s1 = 102
7    addi   $t0,$zero,103 # $t0 = 103
8    addi   $t1,$zero,104 # $t1 = 104
9    addi   $t2,$zero,105 # $t2 = 105
10   addi   $t3,$zero,106 # $t3 = 106
11   addi   $t4,$zero,107 # $t4 = 107
12   addi   $t5,$zero,108 # $t5 = 108
13   addi   $t6,$zero,109 # $t6 = 109
14   addi   $t7,$zero,110 # $t7 = 110
15   addi   $t8,$zero,111 # $t8 = 111
16   addi   $t9,$zero,112 # $t9 = 112
17   addi   $t10,$zero,113 # $t10 = 113
18   addi   $t11,$zero,114 # $t11 = 114
19   addi   $t12,$zero,115 # $t12 = 115
20   addi   $t13,$zero,116 # $t13 = 116
21   addi   $t14,$zero,117 # $t14 = 117
22   addi   $t15,$zero,118 # $t15 = 118
23   addi   $t16,$zero,119 # $t16 = 119
24   addi   $t17,$zero,120 # $t17 = 120
25   addi   $t18,$zero,121 # $t18 = 121
26   addi   $t19,$zero,122 # $t19 = 122
27   addi   $t20,$zero,123 # $t20 = 123
28   addi   $t21,$zero,124 # $t21 = 124
29   addi   $t22,$zero,125 # $t22 = 125
30   addi   $t23,$zero,126 # $t23 = 126
31   addi   $t24,$zero,127 # $t24 = 127
32   addi   $t25,$zero,128 # $t25 = 128
33   addi   $t26,$zero,129 # $t26 = 129
34   addi   $t27,$zero,130 # $t27 = 130
35   addi   $t28,$zero,131 # $t28 = 131
36   addi   $t29,$zero,132 # $t29 = 132
37   addi   $t30,$zero,133 # $t30 = 133
38   addi   $t31,$zero,134 # $t31 = 134
39   addi   $t32,$zero,135 # $t32 = 135
40   addi   $t33,$zero,136 # $t33 = 136
41   addi   $t34,$zero,137 # $t34 = 137
42   addi   $t35,$zero,138 # $t35 = 138
43   addi   $t36,$zero,139 # $t36 = 139
44   addi   $t37,$zero,140 # $t37 = 140
45   addi   $t38,$zero,141 # $t38 = 141
46   addi   $t39,$zero,142 # $t39 = 142
47   addi   $t40,$zero,143 # $t40 = 143
48   addi   $t41,$zero,144 # $t41 = 144
49   addi   $t42,$zero,145 # $t42 = 145
50   addi   $t43,$zero,146 # $t43 = 146
51   addi   $t44,$zero,147 # $t44 = 147
52   addi   $t45,$zero,148 # $t45 = 148
53   addi   $t46,$zero,149 # $t46 = 149
54   addi   $t47,$zero,150 # $t47 = 150
55   addi   $t48,$zero,151 # $t48 = 151
56   addi   $t49,$zero,152 # $t49 = 152
57   addi   $t50,$zero,153 # $t50 = 153
58   addi   $t51,$zero,154 # $t51 = 154
59   addi   $t52,$zero,155 # $t52 = 155
60   addi   $t53,$zero,156 # $t53 = 156
61   addi   $t54,$zero,157 # $t54 = 157
62   addi   $t55,$zero,158 # $t55 = 158
63   addi   $t56,$zero,159 # $t56 = 159
64   addi   $t57,$zero,160 # $t57 = 160
65   addi   $t58,$zero,161 # $t58 = 161
66   addi   $t59,$zero,162 # $t59 = 162
67   addi   $t60,$zero,163 # $t60 = 163
68   addi   $t61,$zero,164 # $t61 = 164
69   addi   $t62,$zero,165 # $t62 = 165
70   addi   $t63,$zero,166 # $t63 = 166
71   addi   $t64,$zero,167 # $t64 = 167
72   addi   $t65,$zero,168 # $t65 = 168
73   addi   $t66,$zero,169 # $t66 = 169
74   addi   $t67,$zero,170 # $t67 = 170
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79   addi   $t72,$zero,175 # $t72 = 175
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82   addi   $t75,$zero,178 # $t75 = 178
83   addi   $t76,$zero,179 # $t76 = 179
84   addi   $t77,$zero,180 # $t77 = 180
85   addi   $t78,$zero,181 # $t78 = 181
86   addi   $t79,$zero,182 # $t79 = 182
87   addi   $t80,$zero,183 # $t80 = 183
88   addi   $t81,$zero,184 # $t81 = 184
89   addi   $t82,$zero,185 # $t82 = 185
90   addi   $t83,$zero,186 # $t83 = 186
91   addi   $t84,$zero,187 # $t84 = 187
92   addi   $t85,$zero,188 # $t85 = 188
93   addi   $t86,$zero,189 # $t86 = 189
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95   addi   $t88,$zero,191 # $t88 = 191
96   addi   $t89,$zero,192 # $t89 = 192
97   addi   $t90,$zero,193 # $t90 = 193
98   addi   $t91,$zero,194 # $t91 = 194
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105  addi   $t98,$zero,201 # $t98 = 201
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112  addi   $t105,$zero,208 # $t105 = 208
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114  addi   $t107,$zero,210 # $t107 = 210
115  addi   $t108,$zero,211 # $t108 = 211
116  addi   $t109,$zero,212 # $t109 = 212
117  addi   $t110,$zero,213 # $t110 = 213
118  addi   $t111,$zero,214 # $t111 = 214
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126  addi   $t119,$zero,222 # $t119 = 222
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144  addi   $t137,$zero,240 # $t137 = 240
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152  addi   $t145,$zero,248 # $t145 = 248
153  addi   $t146,$zero,249 # $t146 = 249
154  addi   $t147,$zero,250 # $t147 = 250
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156  addi   $t149,$zero,252 # $t149 = 252
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162  addi   $t155,$zero,258 # $t155 = 258
163  addi   $t156,$zero,259 # $t156 = 259
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165  addi   $t158,$zero,261 # $t158 = 261
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167  addi   $t160,$zero,263 # $t160 = 263
168  addi   $t161,$zero,264 # $t161 = 264
169  addi   $t162,$zero,265 # $t162 = 265
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171  addi   $t164,$zero,267 # $t164 = 267
172  addi   $t165,$zero,268 # $t165 = 268
173  addi   $t166,$zero,269 # $t166 = 269
174  addi   $t167,$zero,270 # $t167 = 270
175  addi   $t168,$zero,271 # $t168 = 271
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177  addi   $t170,$zero,273 # $t170 = 273
178  addi   $t171,$zero,274 # $t171 = 274
179  addi   $t172,$zero,275 # $t172 = 275
180  addi   $t173,$zero,276 # $t173 = 276
181  addi   $t174,$zero,277 # $t174 = 277
182  addi   $t175,$zero,278 # $t175 = 278
183  addi   $t176,$zero,279 # $t176 = 279
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185  addi   $t178,$zero,281 # $t178 = 281
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189  addi   $t182,$zero,285 # $t182 = 285
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192  addi   $t185,$zero,288 # $t185 = 288
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195  addi   $t188,$zero,291 # $t188 = 291
196  addi   $t189,$zero,292 # $t189 = 292
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198  addi   $t191,$zero,294 # $t191 = 294
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200  addi   $t193,$zero,296 # $t193 = 296
201  addi   $t194,$zero,297 # $t194 = 297
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204  addi   $t197,$zero,300 # $t197 = 300
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206  addi   $t199,$zero,302 # $t199 = 302
207  addi   $t200,$zero,303 # $t200 = 303
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210  addi   $t203,$zero,306 # $t203 = 306
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234  addi   $t227,$zero,330 # $t227 = 330
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236  addi   $t229,$zero,332 # $t229 = 332
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240  addi   $t233,$zero,336 # $t233 = 336
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245  addi   $t238,$zero,341 # $t238 = 341
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248  addi   $t241,$zero,344 # $t241 = 344
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253  addi   $t246,$zero,349 # $t246 = 349
254  addi   $t247,$zero,350 # $t247 = 350
255  addi   $t248,$zero,351 # $t248 = 351
256  addi   $t249,$zero,352 # $t249 = 352
257  addi   $t250,$zero,353 # $t250 = 353
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260  addi   $t253,$zero,356 # $t253 = 356
261  addi   $t254,$zero,357 # $t254 = 357
262  addi   $t255,$zero,358 # $t255 = 358
263  addi   $t256,$zero,359 # $t256 = 359
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266  addi   $t259,$zero,362 # $t259 = 362
267  addi   $t260,$zero,363 # $t260 = 363
268  addi   $t261,$zero,364 # $t261 = 364
269  addi   $t262,$zero,365 # $t262 = 365
270  addi   $t263,$zero,366 # $t263 = 366
271  addi   $t264,$zero,367 # $t264 = 367
272  addi   $t265,$zero,368 # $t265 = 368
273  addi   $t266,$zero,369 # $t266 = 369
274  addi   $t267,$zero,370 # $t267 = 370
275  addi   $t268,$zero,371 # $t268 = 371
276  addi   $t269,$zero,372 # $t269 = 372
277  addi   $t270,$zero,373 # $t270 = 373
278  addi   $t271,$zero,374 # $t271 = 374
279  addi   $t272,$zero,375 # $t272 = 375
280  addi   $t273,$zero,376 # $t273 = 376
281  addi   $t274,$zero,377 # $t274 = 377
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283  addi   $t276,$zero,379 # $t276 = 379
284  addi   $t277,$zero,380 # $t277 = 380
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286  addi   $t279,$zero,382 # $t279 = 382
287  addi   $t280,$zero,383 # $t280 = 383
288  addi   $t281,$zero,384 # $t281 = 384
289  addi   $t282,$zero,385 # $t282 = 385
290  addi   $t283,$zero,386 # $t283 = 386
291  addi   $t284,$zero,387 # $t284 = 387
292  addi   $t285,$zero,388 # $t285 = 388
293  addi   $t286,$zero,389 # $t286 = 389
294  addi   $t287,$zero,390 # $t287 = 390
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296  addi   $t289,$zero,392 # $t289 = 392
297  addi   $t290,$zero,393 # $t290 = 393
298  addi   $t291,$zero,394 # $t291 = 394
299  addi   $t292,$zero,395 # $t292 = 395
300  addi   $t293,$zero,396 # $t293 = 396
301  addi   $t294,$zero,397 # $t294 = 397
302  addi   $t295,$zero,398 # $t295 = 398
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304  addi   $t297,$zero,400 # $t297 = 400
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308  addi   $t301,$zero,404 # $t301 = 404
309  addi   $t302,$zero,405 # $t302 = 405
310  addi   $t303,$zero,406 # $t303 = 406
311  addi   $t304,$zero,407 # $t304 = 407
312  addi   $t305,$zero,408 # $t305 = 408
313  addi   $t306,$zero,409 # $t306 = 409
314  addi   $t307,$zero,410 # $t307 = 410
315  addi   $t308,$zero,411 # $t308 = 411
316  addi   $t309,$zero,412 # $t309 = 412
317  addi   $t310,$zero,413 # $t310 = 413
318  addi   $t311,$zero,414 # $t311 = 414
319  addi   $t312,$zero,415 # $t312 = 415
320  addi   $t313,$zero,416 # $t313 = 416
321  addi   $t314,$zero,417 # $t314 = 417
322  addi   $t315,$zero,418 # $t315 = 418
323  addi   $t316,$zero,419 # $t316 = 419
324  addi   $t317,$zero,420 # $t317 = 420
325  addi   $t318,$zero,421 # $t318 = 421
326  addi   $t319,$zero,422 # $t319 = 422
327  addi   $t320,$zero,423 # $t320 = 423
328  addi   $t321,$zero,424 # $t321 = 424
329  addi   $t322,$zero,425 # $t322 = 425
330  addi   $t323,$zero,426 # $t323 = 426
331  addi   $t324,$zero,427 # $t324 = 427
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333  addi   $t326,$zero,429 # $t326 = 429
334  addi   $t327,$zero,430 # $t327 = 430
335  addi   $t328,$zero,431 # $t328 = 431
336  addi   $t329,$zero,432 # $t329 = 432
337  addi   $t330,$zero,433 # $t330 = 433
338  addi   $t331,$zero,434 # $t331 = 434
339  addi   $t332,$zero,435 # $t332 = 435
340  addi   $t333,$zero,436 # $t333 = 436
341  addi   $t334,$zero,437 # $t334 = 437
342  addi   $t335,$zero,438 # $t335 = 438
343  addi   $t336,$zero,439 # $t336 = 439
344  addi   $t337,$zero,440 # $t337 = 440
345  addi   $t338,$zero,441 # $t338 = 441
346  addi   $t339,$zero,442 # $t339 = 442
347  addi   $t340,$zero,443 # $t340 = 443
348  addi   $t341,$zero,444 # $t341 = 444
349  addi   $t342,$zero,445 # $t342 = 445
350  addi   $t343,$zero,446 # $t343 = 446
351  addi   $t344,$zero,447 # $t344 = 447
352  addi   $t345,$zero,448 # $t345 = 448
353  addi   $t346,$zero,449 # $t346 = 449
354  addi   $t347,$zero,450 # $t347 = 450
355  addi   $t348,$zero,451 # $t348 = 451
356  addi   $t349,$zero,452 # $t349 = 452
357  addi   $t350,$zero,453 # $t350 = 453
358  addi   $t351,$zero,454 # $t351 = 454
359  addi   $t352,$zero,455 # $t352 = 455
360  addi   $t353,$zero,456 # $t353 = 456
361  addi   $t354,$zero,457 # $t354 = 457
362  addi   $t355,$zero,458 # $t355 = 458
363  addi   $t356,$zero,459 # $t356 = 459
364  addi   $t357,$zero,460 # $t357 = 460
365  addi   $t358,$zero,461 # $t358 = 461
366  addi   $t359,$zero,462 # $t359 = 462
367  addi   $t360,$zero,463 # $t360 = 463
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369  addi   $t362,$zero,465 # $t362 = 465
370  addi   $t363,$zero,466 # $t363 = 466
371  addi   $t364,$zero,467 # $t364 = 467
372  addi   $t365,$zero,468 # $t365 = 468
373  addi   $t366,$zero,469 # $t366 = 469
374  addi   $t367,$zero,470 # $t367 = 470
375  addi   $t368,$zero,471 # $t368 = 471
376  addi   $t369,$zero,472 # $t369 = 472
377  addi   $t370,$zero,473 # $t370 = 473
378  addi   $t371,$zero,474 # $t371 = 474
379  addi   $t372,$zero,475 # $t372 = 475
380  addi   $t373,$zero,476 # $t373 = 476
381  addi   $t374,$zero,477 # $t374 = 477
382  addi   $t375,$zero,478 # $t375 = 478
383  addi   $t376,$zero,479 # $t376 = 479
384  addi   $t377,$zero,480 # $t377 = 480
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386  addi   $t379,$zero,482 # $t379 = 482
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388  addi   $t381,$zero,484 # $t381 = 484
389  addi   $t382,$zero,485 # $t382 = 485
390  addi   $t383,$zero,486 # $t383 = 486
391  addi   $t384,$zero,487 # $t384 = 487
392  addi   $t385,$zero,488 # $t385 = 488
393  addi   $t386,$zero,489 # $t386 = 489
394  addi   $t387,$zero,490 # $t387 = 490
395  addi   $t388,$zero,491 # $t388 = 491
396  addi   $t389,$zero,492 # $t389 = 492
397  addi   $t390,$zero,493 # $t390 = 493
398  addi   $t391,$zero,494 # $t391 = 494
399  addi   $t392,$zero,495 # $t392 = 495
400  addi   $t393,$zero,496 # $t393 = 496
401  addi   $t394,$zero,497 # $t394 = 497
402  addi   $t395,$zero,498 # $t395 = 498
403  addi   $t396,$zero,499 # $t396 = 499
404  addi   $t397,$zero,500 # $t397 = 500
405  addi   $t398,$zero,501 # $t398 = 501
406  addi   $t399,$zero,502 # $t399 = 502
407  addi   $t400,$zero,503 # $t400 = 503
408  addi   $t401,$zero,504 # $t401 = 504
409  addi   $t402,$zero,505 # $t402 = 505
410  addi   $t403,$zero,506 # $t403 = 506
411  addi   $t404,$zero,507 # $t404 = 507
412  addi   $t405,$zero,508 # $t405 = 508
413  addi   $t406,$zero,509 # $t406 = 509
414  addi   $t407,$zero,510 # $t407 = 510
415  addi   $t408,$zero,511 # $t408 = 511
416  addi   $t409,$zero,512 # $t409 = 512
417  addi   $t410,$zero,513 # $t410 = 513
418  addi   $t411,$zero,514 # $t411 = 514
419  addi   $t412,$zero,515 # $t412 = 515
420  addi   $t413,$zero,516 # $t413 = 516
42
```

MIPS Commands

- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...
 - **R Instructions:** Commands that use data in the registers:
add \$s1, \$s2, \$s3 (Basic form: OP rd, rs, rt)
 - **I Instructions:** instructions that also use intermediate values.
addi \$s1, \$s2, 100

MIPS Commands

The screenshot shows the ShowMe Demo interface. At the top, there are tabs for User, ShowMe Demo, Addition, Subtraction, Bitwise, Looper, Stack Test, Hello World, Code Gen, Save String, Interactive, Binary, Decimal, and Debug. Below the tabs is a text area containing MIPS assembly code. To the right is a table showing register values.

S	T	A	V	Stack	Log
\$0	10				
\$1	9				
\$2	8				
\$3	22				
\$4	60				
\$5	61				
\$6	807				
\$7	418				

Assembly code (from line 1 to 32):

```
1 # Shows "Hello world" at the top of the stack
2 .text
3 .globl _start
4 _start:
5 #ADD $t0,$zero,$t0 # t0 = 0
6 #ADD $t0,$t0,$t0 # t0 = 1
7 #ADD $t0,$t0,$t0 # t0 = 2
8 #ADD $t0,$t0,$t0 # t0 = 3
9 #ADD $t0,$t0,$t0 # t0 = 4
10 #ADD $t0,$t0,$t0 # t0 = 5
11 #ADD $t0,$t0,$t0 # t0 = 6
12 #ADD $t0,$t0,$t0 # t0 = 7
13 #ADD $t0,$t0,$t0 # t0 = 8
14 #ADD $t0,$t0,$t0 # t0 = 9
15 #ADD $t0,$t0,$t0 # t0 = 10
16 #ADD $t0,$t0,$t0 # t0 = 11
17 #ADD $t0,$t0,$t0 # t0 = 12
18 #ADD $t0,$t0,$t0 # t0 = 13
19 #ADD $t0,$t0,$t0 # t0 = 14
20 #ADD $t0,$t0,$t0 # t0 = 15
21 #ADD $t0,$t0,$t0 # t0 = 16
22 #ADD $t0,$t0,$t0 # t0 = 17
23 #ADD $t0,$t0,$t0 # t0 = 18
24 #ADD $t0,$t0,$t0 # t0 = 19
25 #ADD $t0,$t0,$t0 # t0 = 20
26 #ADD $t0,$t0,$t0 # t0 = 21
27 #ADD $t0,$t0,$t0 # t0 = 22
28 #ADD $t0,$t0,$t0 # t0 = 23
29 #ADD $t0,$t0,$t0 # t0 = 24
30 #ADD $t0,$t0,$t0 # t0 = 25
31 #ADD $t0,$t0,$t0 # t0 = 26
32 #ADD $t0,$t0,$t0 # t0 = 27
# print to the log
# syscall
```

- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...
- **R Instructions:** Commands that use data in the registers:
add \$s1, \$s2, \$s3 (Basic form: OP rd, rs, rt)
- **I Instructions:** instructions that also use intermediate values.
addi \$s1, \$s2, 100 (Basic form: OP rd, rs, imm)
- **J Instructions:** instructions that jump to another memory location.

MIPS Commands

- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...
 - **R Instructions:** Commands that use data in the registers:
add \$s1, \$s2, \$s3 (Basic form: OP rd, rs, rt)
 - **I Instructions:** instructions that also use intermediate values.
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MIPS Commands

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j done (Basic form: OP label)

In Pairs or Triples:

Line: 3 Go! Show/Hide Demos User Guide | Unit Tests | Docs

Addition Doubler Stav Looper Stack Test Hello World

Code Gen Save String Interactive Binary2 Decimal Decimal2 Binary

Debug

```
1 # Store 'Hello world!' at the top of the stack
2 ADDI $sp, $sp, -13
3 ADDI $t0, $zero, 72 # H
4 SB $t0, 0($sp)
5 ADDI $t0, $zero, 101 # e
6 SB $t0, 1($sp)
7 ADDI $t0, $zero, 108 # l
8 SB $t0, 2($sp)
9 ADDI $t0, $zero, 108 # l
10 SB $t0, 3($sp)
11 ADDI $t0, $zero, 111 # o
12 SB $t0, 4($sp)
13 ADDI $t0, $zero, 32 # (space)
14 SB $t0, 5($sp)
15 ADDI $t0, $zero, 119 # w
16 SB $t0, 6($sp)
17 ADDI $t0, $zero, 111 # o
18 SB $t0, 7($sp)
19 ADDI $t0, $zero, 114 # r
20 SB $t0, 8($sp)
21 ADDI $t0, $zero, 108 # l
22 SB $t0, 9($sp)
23 ADDI $t0, $zero, 100 # d
24 SB $t0, 10($sp)
25 ADDI $t0, $zero, 33 # !
26 SB $t0, 11($sp)
27 ADDI $t0, $zero, 0 # (null)
28 SB $t0, 12($sp)
29
30 ADDI $v0, $zero, 4 # 4 is for print string
31 ADDI $a0, $sp, 0      # print to the log
32 syscall
```

Step Run Enable auto switching

S	T	A	V	Stack	Log
s0:				10	
s1:				9	
s2:				9	
s3:				22	
s4:				696	
s5:				976	
s6:				927	
s7:				418	

Write a program that prints out the alphabet: a b c d ... x y z

WeMIPS

(Demo with WeMIPS)

Today's Topics



- Design Patterns: Searching
- Python Recap
- Machine Language
- **Machine Language: Jumps & Loops**
- Binary & Hex Arithmetic
- Final Exam: Format

Loops & Jumps in Machine Language

- Instead of built-in looping structures like `for` and `while`, you create your own loops by “jumping” to the location in the program.



Loops & Jumps in Machine Language

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A screenshot of a hex editor application. The left pane shows a list of memory pages, each containing a series of memory addresses and their corresponding byte values. The right pane is a detailed view of a specific page, showing memory addresses from 0x00000000 to 0x0000000F. The bytes displayed are: 48 45 4C 4C 4D 4E 4F 4F 4A 4B 4C 4D 4E 4F 4F 4A 4B 4C. Below the address 0x00000000, there is a label 'Label' followed by a colon and the assembly instruction 'JMP Label'. The bottom of the window has standard file menu options like File, Edit, View, Insert, Options, Window, and Help.

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 - ▶ See reading for more variations.



Jump Demo

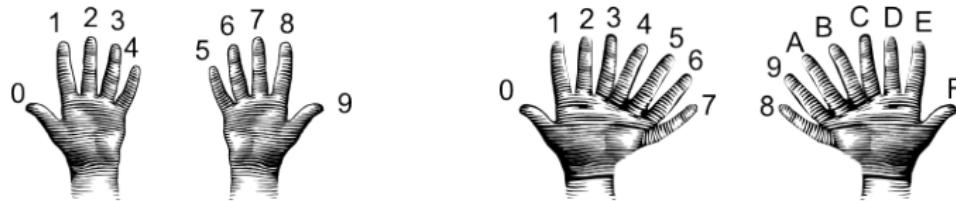
(Demo with WeMIPS)

Today's Topics



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- Machine Language: Jumps & Loops
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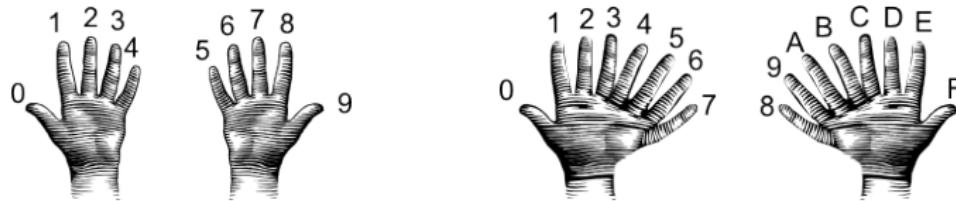
Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal:
 - Convert first digit to decimal and multiple by 16.

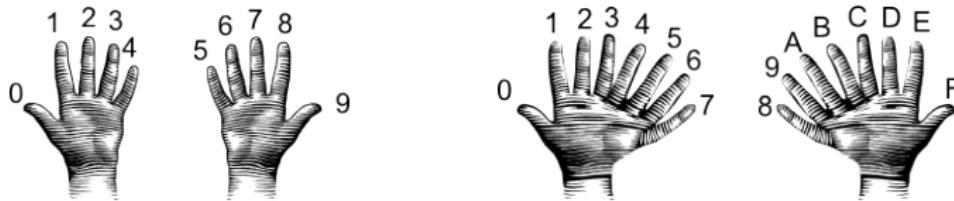
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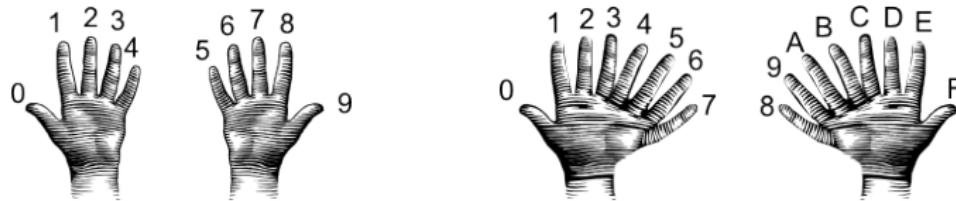


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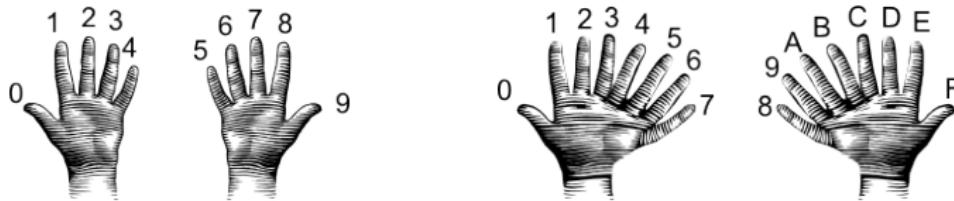
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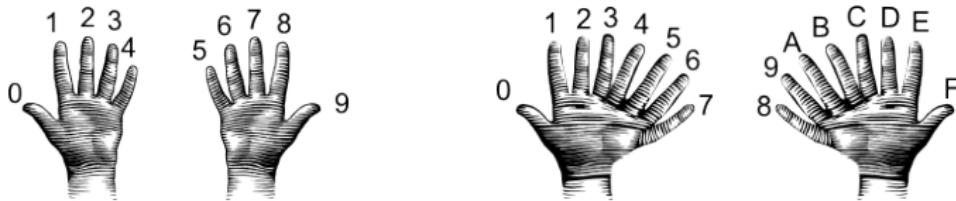
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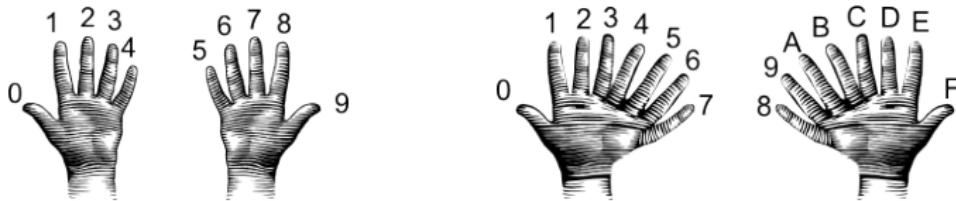
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A in decimal digits is 10.

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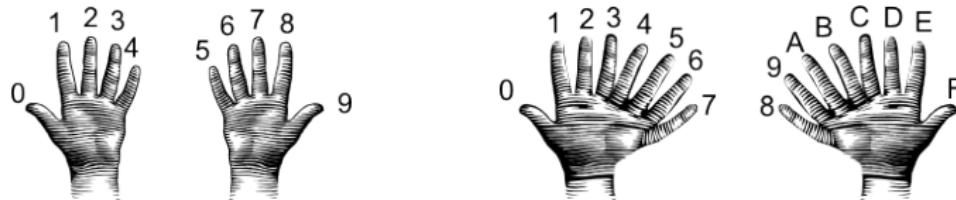
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2 in decimal is 2. 2×16 is 32.

A in decimal digits is 10.

$32 + 10$ is 42.

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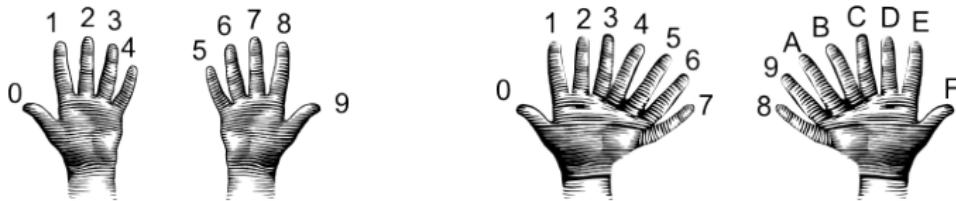
A in decimal digits is 10.

$32 + 10$ is 42.

Answer is 42.

- Example: what is 99 as a decimal number?

Hexadecimal to Decimal: Converting Between Bases



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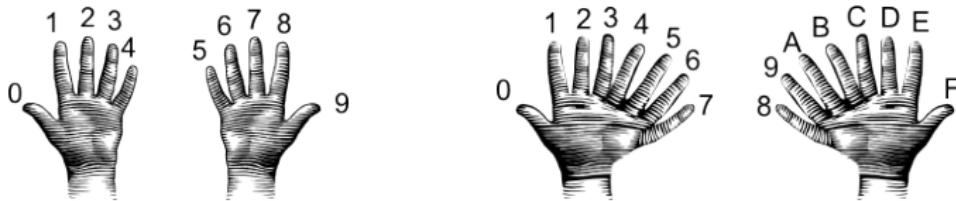
$32 + 10$ is 42.

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- Example: what is 99 as a decimal number?

9 in decimal is 9.

Hexadecimal to Decimal: Converting Between Bases



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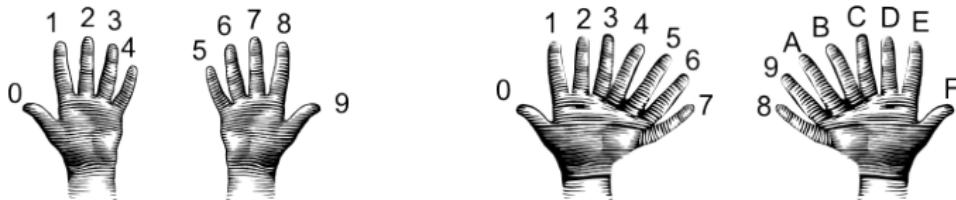
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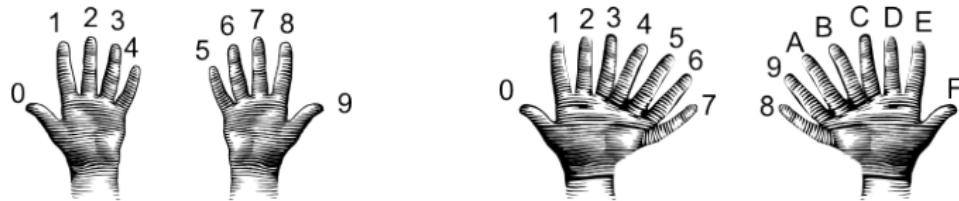
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Hexadecimal to Decimal: Converting Between Bases



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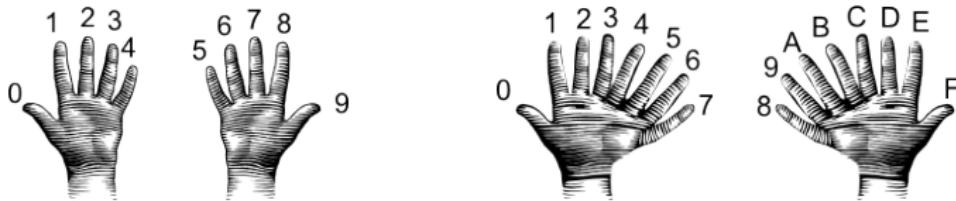
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$144 + 9$ is 153.

Hexadecimal to Decimal: Converting Between Bases



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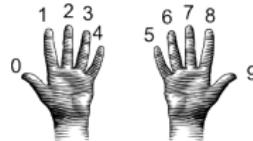
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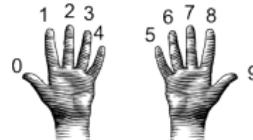
Answer is 153.

Decimal to Binary: Converting Between Bases



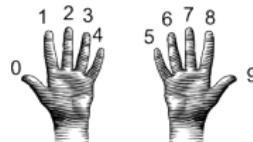
- From decimal to binary:
 - Divide by 128 ($= 2^7$). Quotient is the first digit.

Decimal to Binary: Converting Between Bases



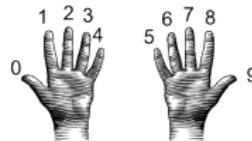
- From decimal to binary:
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Decimal to Binary: Converting Between Bases



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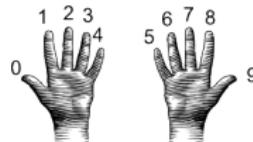
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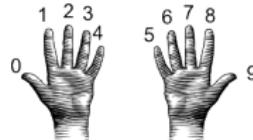
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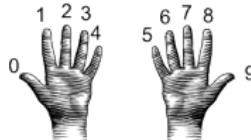
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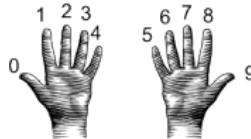
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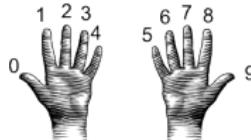
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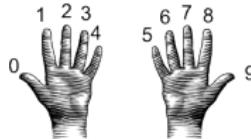
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Decimal to Binary: Converting Between Bases

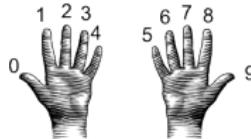


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130/128 is 1 rem 2.

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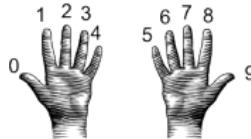


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Decimal to Binary: Converting Between Bases



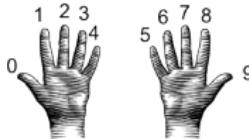
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Decimal to Binary: Converting Between Bases



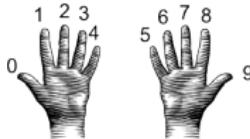
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Decimal to Binary: Converting Between Bases



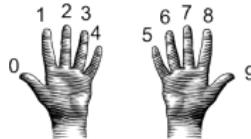
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Decimal to Binary: Converting Between Bases



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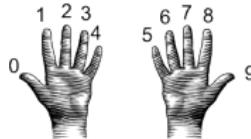
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- ▶ Divide remainder by $32 (= 2^5)$. Quotient is the next digit.
- ▶ Divide remainder by $16 (= 2^4)$. Quotient is the next digit.
- ▶ Divide remainder by $8 (= 2^3)$. Quotient is the next digit.
- ▶ Divide remainder by $4 (= 2^2)$. Quotient is the next digit.
- ▶ Divide remainder by $2 (= 2^1)$. Quotient is the next digit.
- ▶ The last remainder is the last digit.
- ▶ Example: what is 130 in binary notation?

130/128 is 1 rem 2. First digit is 1: 1...

2/64 is 0 rem 2. Next digit is 0: 10...

2/32 is 0 rem 2.

Decimal to Binary: Converting Between Bases



- From decimal to binary:

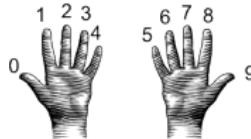
- ▶ Divide by $128 (= 2^7)$. Quotient is the first digit.
- ▶ Divide remainder by $64 (= 2^6)$. Quotient is the next digit.
- ▶ Divide remainder by $32 (= 2^5)$. Quotient is the next digit.
- ▶ Divide remainder by $16 (= 2^4)$. Quotient is the next digit.
- ▶ Divide remainder by $8 (= 2^3)$. Quotient is the next digit.
- ▶ Divide remainder by $4 (= 2^2)$. Quotient is the next digit.
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- ▶ The last remainder is the last digit.
- ▶ Example: what is 130 in binary notation?

130/128 is 1 rem 2. First digit is 1: 1...

2/64 is 0 rem 2. Next digit is 0: 10...

2/32 is 0 rem 2. Next digit is 0:

Decimal to Binary: Converting Between Bases



- From decimal to binary:

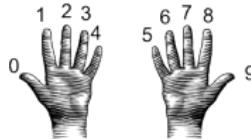
- ▶ Divide by $128 (= 2^7)$. Quotient is the first digit.
- ▶ Divide remainder by $64 (= 2^6)$. Quotient is the next digit.
- ▶ Divide remainder by $32 (= 2^5)$. Quotient is the next digit.
- ▶ Divide remainder by $16 (= 2^4)$. Quotient is the next digit.
- ▶ Divide remainder by $8 (= 2^3)$. Quotient is the next digit.
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- ▶ Divide remainder by $2 (= 2^1)$. Quotient is the next digit.
- ▶ The last remainder is the last digit.
- ▶ Example: what is 130 in binary notation?

130/128 is 1 rem 2. First digit is 1: 1...

2/64 is 0 rem 2. Next digit is 0: 10...

2/32 is 0 rem 2. Next digit is 0: 100...

Decimal to Binary: Converting Between Bases



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- ▶ Divide remainder by $8 (= 2^3)$. Quotient is the next digit.
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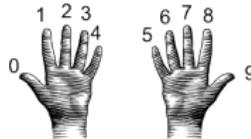
130/128 is 1 rem 2. First digit is 1: 1...

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2/16 is 0 rem 2.

Decimal to Binary: Converting Between Bases



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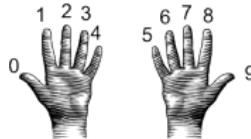
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2/64 is 0 rem 2. Next digit is 0: 10...

2/32 is 0 rem 2. Next digit is 0: 100...

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Decimal to Binary: Converting Between Bases



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- Divide by $128 (= 2^7)$. Quotient is the first digit.
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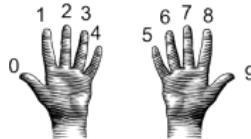
130/128 is 1 rem 2. First digit is 1: 1...

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2/32 is 0 rem 2. Next digit is 0: 100...

2/16 is 0 rem 2. Next digit is 0: 1000...

Decimal to Binary: Converting Between Bases



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130/128 is 1 rem 2. First digit is 1: 1...

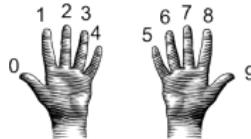
2/64 is 0 rem 2. Next digit is 0: 10...

2/32 is 0 rem 2. Next digit is 0: 100...

2/16 is 0 rem 2. Next digit is 0: 1000...

2/8 is 0 rem 2.

Decimal to Binary: Converting Between Bases



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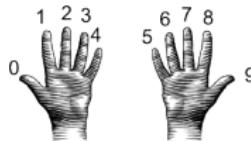
2/64 is 0 rem 2. Next digit is 0: 10...

2/32 is 0 rem 2. Next digit is 0: 100...

2/16 is 0 rem 2. Next digit is 0: 1000...

2/8 is 0 rem 2. Next digit is 0:

Decimal to Binary: Converting Between Bases



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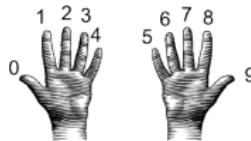
2/64 is 0 rem 2. Next digit is 0: 10...

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Decimal to Binary: Converting Between Bases



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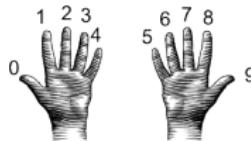
2/32 is 0 rem 2. Next digit is 0: 100...

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2/8 is 0 rem 2. Next digit is 0: 10000...

2/4 is 0 remainder 2.

Decimal to Binary: Converting Between Bases



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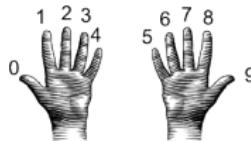
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2/16 is 0 rem 2. Next digit is 0: 1000...

2/8 is 0 rem 2. Next digit is 0: 10000...

2/4 is 0 remainder 2. Next digit is 0:

Decimal to Binary: Converting Between Bases



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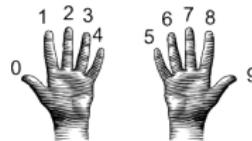
2/32 is 0 rem 2. Next digit is 0: 100...

2/16 is 0 rem 2. Next digit is 0: 1000...

2/8 is 0 rem 2. Next digit is 0: 10000...

2/4 is 0 remainder 2. Next digit is 0: 100000...

Decimal to Binary: Converting Between Bases



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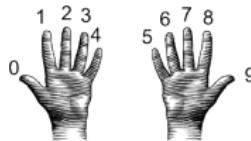
2/16 is 0 rem 2. Next digit is 0: 1000...

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2/2 is 1 rem 0.

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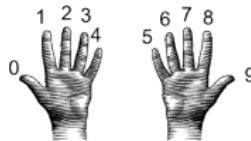
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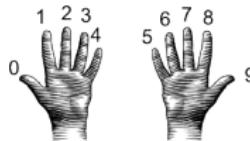
2/16 is 0 rem 2. Next digit is 0: 1000...

2/8 is 0 rem 2. Next digit is 0: 10000...

2/4 is 0 remainder 2. Next digit is 0: 100000...

2/2 is 1 rem 0. Next digit is 1: 1000001...

Decimal to Binary: Converting Between Bases



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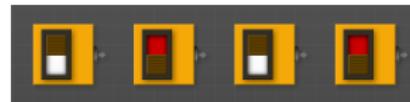
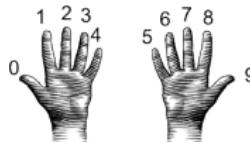
2/8 is 0 rem 2. Next digit is 0: 10000...

2/4 is 0 remainder 2. Next digit is 0: 100000...

2/2 is 1 rem 0. Next digit is 1: 1000001...

Adding the last remainder: 10000010

Decimal to Binary: Converting Between Bases



- From decimal to binary:

- Divide by 128 ($= 2^7$). Quotient is the first digit.
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2/8 is 0 rem 2. Next digit is 0: 10000...

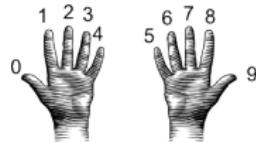
2/4 is 0 remainder 2. Next digit is 0: 100000...

2/2 is 1 rem 0. Next digit is 1: 1000001...

Adding the last remainder:

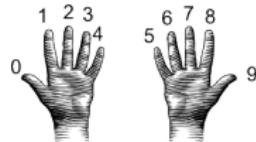
10000010

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

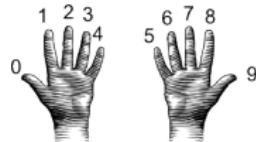
Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

$99/128 \text{ is } 0 \text{ rem } 99.$

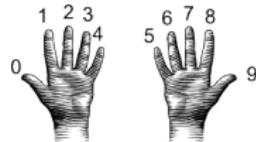
Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

$99/128$ is 0 rem 99. First digit is 0:

Decimal to Binary: Converting Between Bases

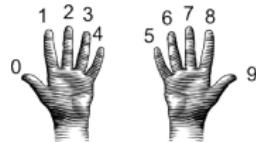


- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35.

Decimal to Binary: Converting Between Bases

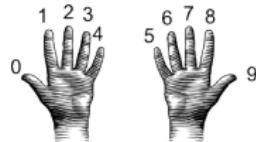


- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1:

Decimal to Binary: Converting Between Bases

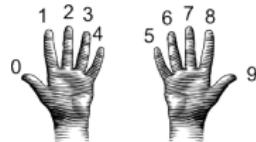


- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

Decimal to Binary: Converting Between Bases



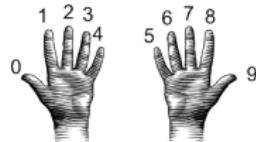
- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3.

Decimal to Binary: Converting Between Bases



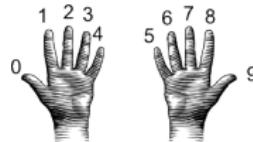
- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1:

Decimal to Binary: Converting Between Bases



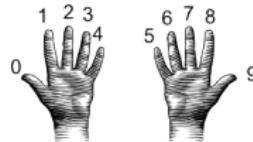
- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

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35/32 is 1 rem 3. Next digit is 1: 011...

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

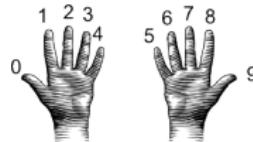
99/128 is 0 rem 99. First digit is 0: 0...

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35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3.

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

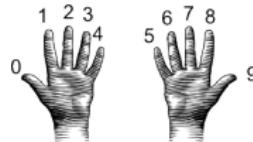
99/128 is 0 rem 99. First digit is 0: 0...

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35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0:

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

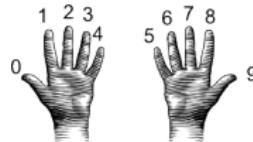
99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0: 0110...

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

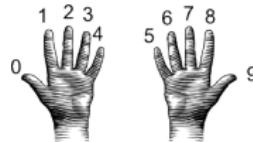
99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3.

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

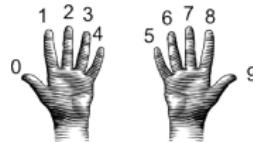
99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3. Next digit is 0:

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

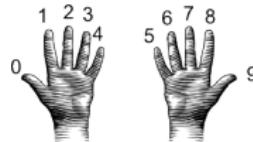
99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3. Next digit is 0: 01100...

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

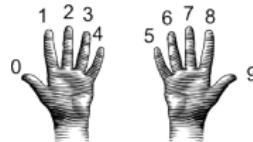
35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3. Next digit is 0: 01100...

3/4 is 0 remainder 3.

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

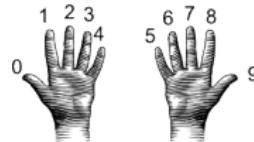
35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3. Next digit is 0: 01100...

3/4 is 0 remainder 3. Next digit is 0:

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

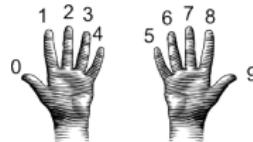
35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3. Next digit is 0: 01100...

3/4 is 0 remainder 3. Next digit is 0: 011000...

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1: 011...

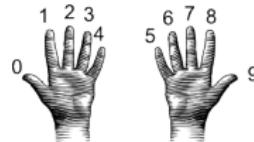
3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3. Next digit is 0: 01100...

3/4 is 0 remainder 3. Next digit is 0: 011000...

3/2 is 1 rem 1.

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1: 011...

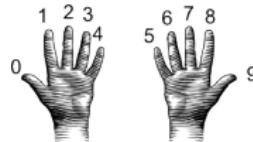
3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3. Next digit is 0: 01100...

3/4 is 0 remainder 3. Next digit is 0: 011000...

3/2 is 1 rem 1. Next digit is 1:

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1: 011...

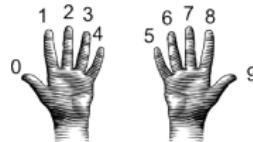
3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3. Next digit is 0: 01100...

3/4 is 0 remainder 3. Next digit is 0: 011000...

3/2 is 1 rem 1. Next digit is 1: 0110001...

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0: 0110...

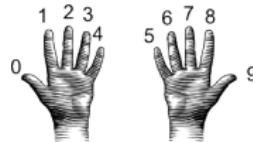
3/8 is 0 rem 3. Next digit is 0: 01100...

3/4 is 0 remainder 3. Next digit is 0: 011000...

3/2 is 1 rem 1. Next digit is 1: 0110001...

Adding the last remainder: 01100011

Decimal to Binary: Converting Between Bases



- Example: what is 99 in binary notation?

99/128 is 0 rem 99. First digit is 0: 0...

99/64 is 1 rem 35. Next digit is 1: 01...

35/32 is 1 rem 3. Next digit is 1: 011...

3/16 is 0 rem 3. Next digit is 0: 0110...

3/8 is 0 rem 3. Next digit is 0: 01100...

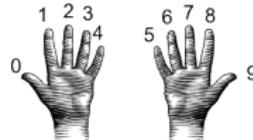
3/4 is 0 remainder 3. Next digit is 0: 011000...

3/2 is 1 rem 1. Next digit is 1: 0110001...

Adding the last remainder: 01100011

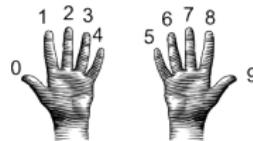
Answer is 1100011.

Binary to Decimal: Converting Between Bases



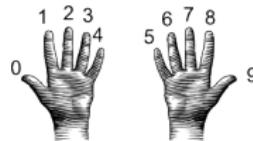
- From binary to decimal:
 - Set sum = last digit.

Binary to Decimal: Converting Between Bases



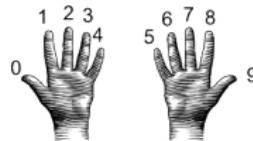
- From binary to decimal:
 - Set sum = last digit.
 - Multiply next digit by 2^1 . Add to sum.

Binary to Decimal: Converting Between Bases



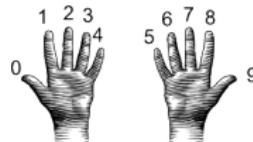
- From binary to decimal:
 - Set sum = last digit.
 - Multiply next digit by $2 = 2^1$. Add to sum.
 - Multiply next digit by $4 = 2^2$. Add to sum.

Binary to Decimal: Converting Between Bases



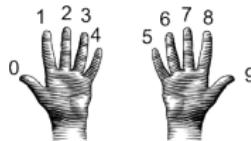
- From binary to decimal:
 - ▶ Set sum = last digit.
 - ▶ Multiply next digit by 2^1 . Add to sum.
 - ▶ Multiply next digit by 2^2 . Add to sum.
 - ▶ Multiply next digit by 2^3 . Add to sum.

Binary to Decimal: Converting Between Bases



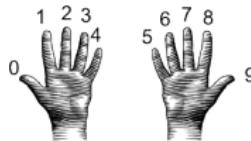
- From binary to decimal:
 - Set sum = last digit.
 - Multiply next digit by 2^1 . Add to sum.
 - Multiply next digit by $4 = 2^2$. Add to sum.
 - Multiply next digit by $8 = 2^3$. Add to sum.
 - Multiply next digit by $16 = 2^4$. Add to sum.

Binary to Decimal: Converting Between Bases



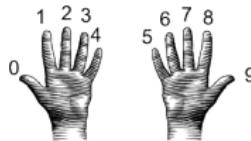
- From binary to decimal:
 - Set sum = last digit.
 - Multiply next digit by 2^1 . Add to sum.
 - Multiply next digit by $4 = 2^2$. Add to sum.
 - Multiply next digit by $8 = 2^3$. Add to sum.
 - Multiply next digit by $16 = 2^4$. Add to sum.
 - Multiply next digit by $32 = 2^5$. Add to sum.

Binary to Decimal: Converting Between Bases



- From binary to decimal:
 - ▶ Set sum = last digit.
 - ▶ Multiply next digit by 2^1 . Add to sum.
 - ▶ Multiply next digit by $4 = 2^2$. Add to sum.
 - ▶ Multiply next digit by $8 = 2^3$. Add to sum.
 - ▶ Multiply next digit by $16 = 2^4$. Add to sum.
 - ▶ Multiply next digit by $32 = 2^5$. Add to sum.
 - ▶ Multiply next digit by $64 = 2^6$. Add to sum.

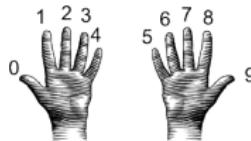
Binary to Decimal: Converting Between Bases



- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.

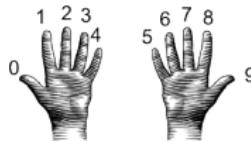
Binary to Decimal: Converting Between Bases



- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.

Binary to Decimal: Converting Between Bases

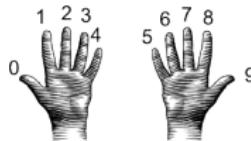


- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with:

Binary to Decimal: Converting Between Bases

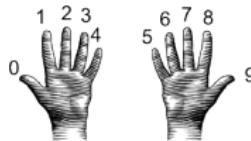


- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with: 1
 $0 * 2 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases

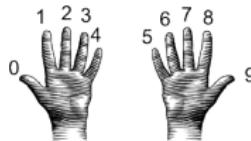


- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1

Binary to Decimal: Converting Between Bases



- From binary to decimal:

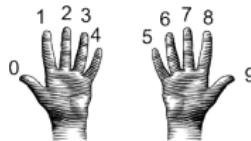
- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with: 1

$0 * 2 = 0$. Add 0 to sum: 1

$1 * 4 = 4$. Add 4 to sum:

Binary to Decimal: Converting Between Bases



- From binary to decimal:

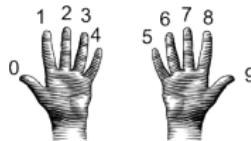
- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with: 1

$0 * 2 = 0$. Add 0 to sum: 1

$1 * 4 = 4$. Add 4 to sum: 5

Binary to Decimal: Converting Between Bases



- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

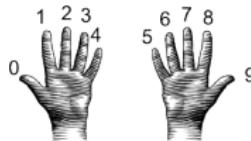
Sum starts with: 1

$0 * 2 = 0$. Add 0 to sum: 1

$1 * 4 = 4$. Add 4 to sum: 5

$1 * 8 = 8$. Add 8 to sum:

Binary to Decimal: Converting Between Bases

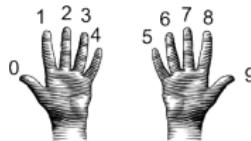


- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with:	1	
$0 * 2 = 0$.	Add 0 to sum:	1
$1 * 4 = 4$.	Add 4 to sum:	5
$1 * 8 = 8$.	Add 8 to sum:	13

Binary to Decimal: Converting Between Bases

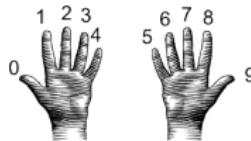


- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \cdot 2 = 0$. Add 0 to sum: 1
 $1 \cdot 4 = 4$. Add 4 to sum: 5
 $1 \cdot 8 = 8$. Add 8 to sum: 13
 $1 \cdot 16 = 16$. Add 16 to sum:

Binary to Decimal: Converting Between Bases

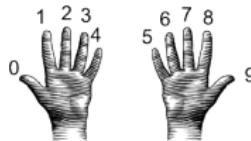


- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with:	1
$0*2 = 0$. Add 0 to sum:	1
$1*4 = 4$. Add 4 to sum:	5
$1*8 = 8$. Add 8 to sum:	13
$1*16 = 16$. Add 16 to sum:	29

Binary to Decimal: Converting Between Bases

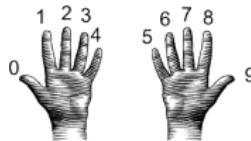


- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with:	1
$0 \cdot 2 = 0$. Add 0 to sum:	1
$1 \cdot 4 = 4$. Add 4 to sum:	5
$1 \cdot 8 = 8$. Add 8 to sum:	13
$1 \cdot 16 = 16$. Add 16 to sum:	29
$1 \cdot 32 = 32$. Add 32 to sum:	

Binary to Decimal: Converting Between Bases

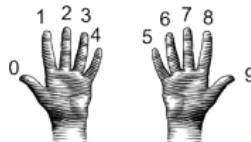


- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with:	1
$0 \cdot 2 = 0$. Add 0 to sum:	1
$1 \cdot 4 = 4$. Add 4 to sum:	5
$1 \cdot 8 = 8$. Add 8 to sum:	13
$1 \cdot 16 = 16$. Add 16 to sum:	29
$1 \cdot 32 = 32$. Add 32 to sum:	61

Binary to Decimal: Converting Between Bases

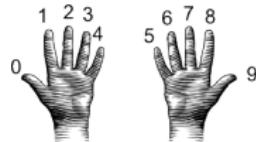


- From binary to decimal:

- Set sum = last digit.
- Multiply next digit by 2^1 . Add to sum.
- Multiply next digit by $4 = 2^2$. Add to sum.
- Multiply next digit by $8 = 2^3$. Add to sum.
- Multiply next digit by $16 = 2^4$. Add to sum.
- Multiply next digit by $32 = 2^5$. Add to sum.
- Multiply next digit by $64 = 2^6$. Add to sum.
- Multiply next digit by $128 = 2^7$. Add to sum.
- Sum is the decimal number.
- Example: What is 111101 in decimal?

Sum starts with:	1
$0 \cdot 2 = 0$. Add 0 to sum:	1
$1 \cdot 4 = 4$. Add 4 to sum:	5
$1 \cdot 8 = 8$. Add 8 to sum:	13
$1 \cdot 16 = 16$. Add 16 to sum:	29
$1 \cdot 32 = 32$. Add 32 to sum:	61

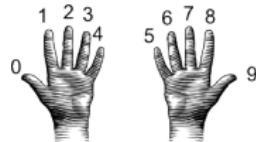
Binary to Decimal: Converting Between Bases



- Example: What is 10100100 in decimal?

Sum starts with:

Binary to Decimal: Converting Between Bases

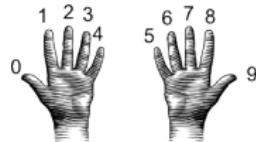


- Example: What is 10100100 in decimal?

Sum starts with: 0

$0 * 2 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases

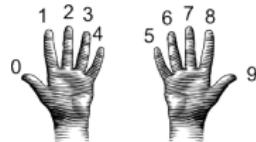


- Example: What is 10100100 in decimal?

Sum starts with: 0

$0 * 2 = 0.$ Add 0 to sum: 0

Binary to Decimal: Converting Between Bases



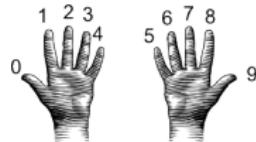
- Example: What is 10100100 in decimal?

Sum starts with: 0

$0 * 2 = 0$. Add 0 to sum: 0

$1 * 4 = 4$. Add 4 to sum:

Binary to Decimal: Converting Between Bases



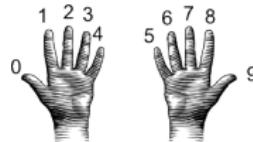
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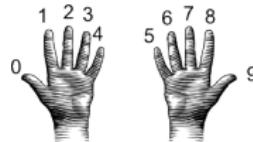
Sum starts with: 0

$0*2 = 0$. Add 0 to sum: 0

$1*4 = 4$. Add 4 to sum: 4

$0*8 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases



- Example: What is 10100100 in decimal?

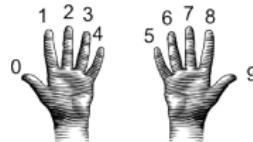
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$1*4 = 4$. Add 4 to sum: 4

$0*8 = 0$. Add 0 to sum: 4

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- Example: What is 10100100 in decimal?

Sum starts with: 0

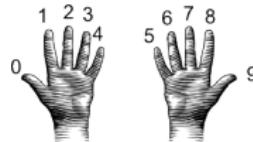
$0 \times 2 = 0$. Add 0 to sum: 0

$1 \times 4 = 4$. Add 4 to sum: 4

$0 \times 8 = 0$. Add 0 to sum: 4

$0 \times 16 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases



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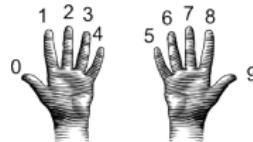
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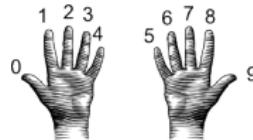
$1 \times 4 = 4$. Add 4 to sum: 4

$0 \times 8 = 0$. Add 0 to sum: 4

$0 \times 16 = 0$. Add 0 to sum: 4

$1 \times 32 = 32$. Add 32 to sum:

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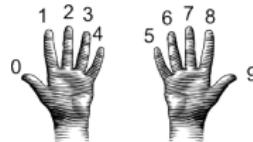
$1 \times 4 = 4$. Add 4 to sum: 4

$0 \times 8 = 0$. Add 0 to sum: 4

$0 \times 16 = 0$. Add 0 to sum: 4

$1 \times 32 = 32$. Add 32 to sum: 36

Binary to Decimal: Converting Between Bases



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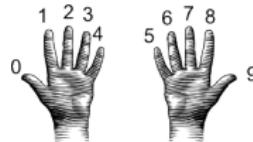
$0 \times 8 = 0$. Add 0 to sum: 4

$0 \times 16 = 0$. Add 0 to sum: 4

$1 \times 32 = 32$. Add 32 to sum: 36

$0 \times 64 = 0$. Add 0 to sum:

Binary to Decimal: Converting Between Bases



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Sum starts with: 0

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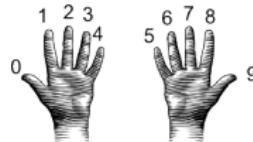
$0 \times 8 = 0$. Add 0 to sum: 4

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Sum starts with: 0

$0 \times 2 = 0$. Add 0 to sum: 0

$1 \times 4 = 4$. Add 4 to sum: 4

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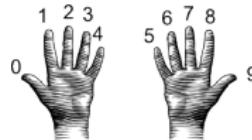
$0 \times 16 = 0$. Add 0 to sum: 4

$1 \times 32 = 32$. Add 32 to sum: 36

$0 \times 64 = 0$. Add 0 to sum: 36

$1 \times 128 = 0$. Add 128 to sum:

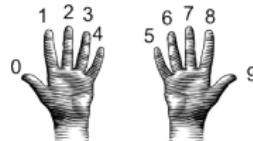
Binary to Decimal: Converting Between Bases



- Example: What is 10100100 in decimal?

Sum starts with:	0
$0 \times 2 = 0$. Add 0 to sum:	0
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$0 \times 16 = 0$. Add 0 to sum:	4
$1 \times 32 = 32$. Add 32 to sum:	36
$0 \times 64 = 0$. Add 0 to sum:	36
$1 \times 128 = 128$. Add 128 to sum:	164

Binary to Decimal: Converting Between Bases

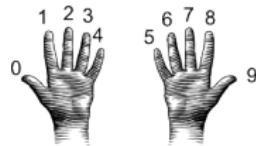


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Sum starts with:	0
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$0 \times 16 = 0$. Add 0 to sum:	4
$1 \times 32 = 32$. Add 32 to sum:	36
$0 \times 64 = 0$. Add 0 to sum:	36
$1 \times 128 = 128$. Add 128 to sum:	164

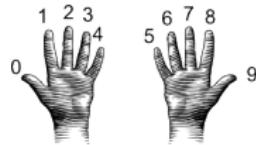
The answer is 164.

Design Challenge: Incrementers



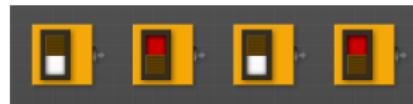
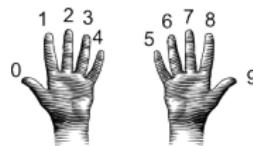
- Simplest arithmetic: add one ("increment") a variable.

Design Challenge: Incrementers



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- Example: Increment a decimal number:

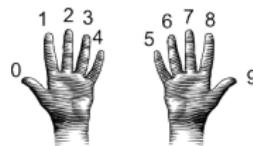
Design Challenge: Incrementers



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```
def addOne(n):  
    m = n+1  
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```

Design Challenge: Incrementers

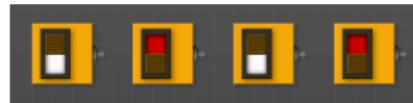
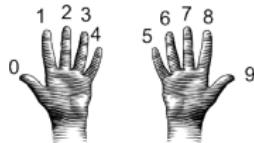


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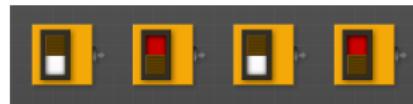
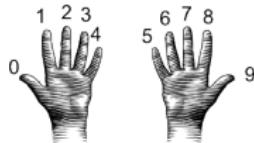


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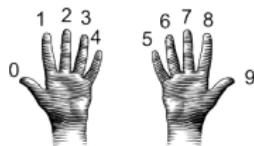


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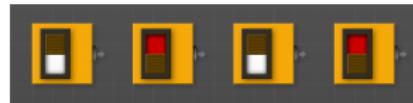
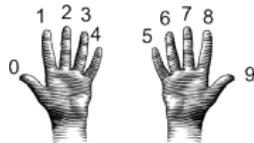


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Design Challenge: Incrementers



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Hint: Convert to numbers, increment, and convert back to strings.
- Challenge: Write an algorithm for incrementing binary numbers.
Example: "1001" → "1010"

Recap

- On lecture slip, write down a topic you wish we had spent more time (and why).



Recap



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- Pass your lecture slips to the aisles for the UTAs to collect.

Today's Topics



- Design Patterns: Searching
- Python Recap
- Machine Language
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic
- **Final Exam: Format**

Final Overview: Format

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- Past exams available on webpage (includes answer keys).

Exam Options

Exam Times:

FINAL EXAM, VERSION 3
CSci 127: Introduction to Computer Science
Hunter College, City University of New York

18 December 2018

Exam Rules

- Show all your work. Your grade will be based on the work shown.
- You may bring one closed book and three notes with the exception of an 8.5" x 11" piece of paper filled with notes, programs, etc.
- When taking the exam, you may have white pens and pencils, and your note sheet.
- You may not use calculators, electronic calculators, mobile phones, or other electronic devices.
- Do not open this exam until instructed to do so.

Hunter College regards acts of academic dishonesty (e.g., plagiarism, cheating on examinations, offering unfair advantages, and fabrication of records and official documents) as serious offenses against the integrity of the educational process. The Hunter College Student Handbook (Section 10.2) lays down the rules for dealing with such acts. Students found guilty of academic honesty will be subject to the Hunter College Academic Honesty Procedure.

<small>I understand that all cases of academic dishonesty will be reported to the Dean of Students and Student Conduct.</small>
Name _____
Signature _____
Date _____
Signature _____

Exam Options

Exam Times:

- Default: Regular Time: Monday, 16 December, 9-11am.
- Alternate Time: Reading Day, Friday, 13 December, 8:30am-10:30am.
- Accessibility Testing Center: Paperwork required. Must be completed on 13 December.

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Name:	
Sugih	
Daniel	
Rajaram	

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Students must affix their name to the line of handwriting and print below.
Name:
Signature:
Handwriting:
Date:
Signature:

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Forms for your choices (“pink slips”) available next lecture.

Writing Boards



- Return writing boards as you leave...