

CSci 127: Introduction to Computer Science



hunter.cuny.edu/csci

- This lecture will be recorded

Announcements

- Great mentoring opportunity available!
Please check out BB announcement from
yesterday 4/19



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 - ▶ Be very comfortable with our labs and programming assignments
 - ▶ Be able to describe a successful tutoring experience (go to tutoring!!!)
 - ▶ Previous tutoring experience helpful but not expected

Frequently Asked Questions

From email and tutoring.

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- ▶ *All previous final exams (and answer keys) on the website.*
- ▶ *UTAs in drop-in tutoring happy to review concepts and old exam questions.*
- ▶ *There will be opportunity for some practice during our last meeting on 11 May.*

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**
- Python Recap
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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.')
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Python Tutor

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(Demo with pythonTutor)

Design Pattern: Linear Search

- Example of **linear search**.

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

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!")
```

← *Prints the string "Hello, World!" to the screen*

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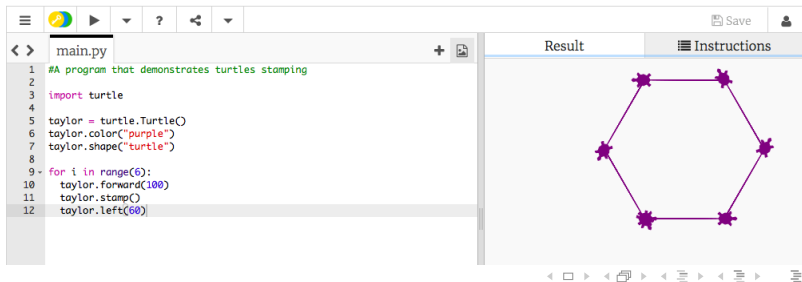
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← (this one also)

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← Prints the string "Hello, World!" to the screen

- As well as definite loops & the turtle package:



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

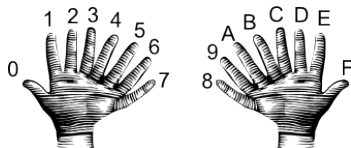
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 - ▶ **class variables**: for complex objects, like turtles.
- More on loops & ranges:

```
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(sum)
12
13 for c in "ABCD":
14     print(c)
```

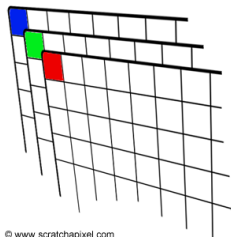
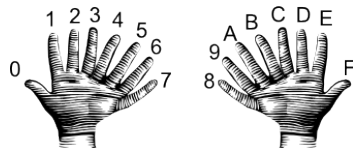
Week 3: colors, hex, slices, numpy & images

Color Name	HEX	Color
Black	#000000	
Navy	#000080	
DarkBlue	#00008B	
MediumBlue	#0000CD	
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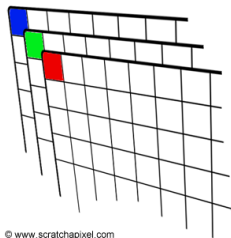
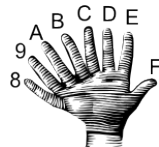
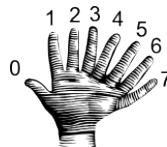
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```
>>> a[0,3:5]  
array([3,4])
```

```
>>> 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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- First: specify inputs/outputs. *Input file name, output file name, upper, lower, left, right* (“bounding box”)
- 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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- 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.")

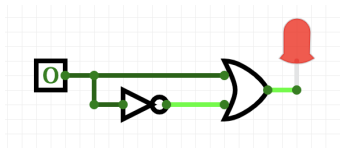
visibility = 0.2
winds = 40
conditions = "blowing snow"
if (winds > 35) and (visibility < 0.25) and \
    (conditions == "blowing snow" or conditions == "heavy snow"):
    print("Blizzard!")
```

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in1		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
1698,4937,2017,,,727,7681
1771,21883,3623,,,2847,28423
1790,,30131,45049,6159,1781,3827,49447
1800,40515,5740,6642,1755,4563,79215
1810,96373,40203,7444,2267,5347,119734
1820,123706,11187,8246,2782,6135,152056
1830,202589,20535,9049,3023,7082,242278
1840,312710,47613,14480,3344,10965,391114
1850,515547,138882,18593,8032,15061,696115
1860,813649,279122,32963,23593,25492,1174779
1870,942292,419921,45468,37393,33829,1470183
1880,1164673,599495,56559,51980,38991,1911690
1890,1441216,838547,87050,88908,51692,2507414
1900,1650093,1146582,152899,200507,67021,3437202
1910,2331542,1634351,284041,430980,85969,4766883
1920,2284103,2018264,469042,732018,116531,5620048
1930,1867312,2560461,1079129,1265258,159346,6306446
1940,1889924,2698285,1297634,1394711,174441,7454995
1950,1940101,2738275,1550849,1452177,291555,78991957
1960,1698281,2627319,1809578,1424815,221993,7781984
1970,1539233,2602012,1986473,1471701,295443,7894862
1980,1428285,2230936,1801325,1168872,352121,7071439
1990,1487536,2300644,1951598,1203789,378977,7322564
2000,1537195,2465326,2229379,1332650,443728,8006278
2010,1494873,2504790,2230722,1385108,448730,8175123
2015,1644518,2636735,2339150,1455444,476558,8550405
```

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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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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```
pop.plot(x="Year")
plt.show()
```

```
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
1698,4937,2017,,,727,7681
1771,21863,3623,,,2847,28423
1790,33131,45049,6159,1781,3827,49447
1800,40515,5740,6642,1755,4563,79215
1810,96373,40203,7444,2267,5347,119734
1820,123706,11187,8246,2782,6135,152056
1830,202589,20535,9049,3023,7082,242278
1840,312710,47613,14480,3344,10965,391114
1850,515547,138882,18593,8032,15061,696115
1860,813649,279122,32963,23593,25492,1174779
1870,942292,419801,45468,37393,33829,1470103
1880,1164673,599495,56559,51980,38991,1911698
1890,1441216,838547,87050,88908,51692,2507414
1900,1650093,1146582,152899,200507,67021,24372702
1910,2331542,1634351,284041,430980,85969,4766883
1920,2284103,2018256,469042,732016,116511,5620048
1930,1867312,2580461,1079129,1265258,159346,6506446
1940,1889924,2698285,1297634,1394711,174441,7454995
1950,1940101,2738275,1500449,1451277,191555,78991957
1960,1698281,2627319,1809578,1624815,221993,7781984
1970,1539233,2602012,1986473,1471701,295443,7894862
1980,1428285,2230936,1801325,1168872,352121,7071639
1990,1487536,2300644,1951598,1203789,378977,7322564
2000,1537195,2465326,2229379,1332650,443728,8006278
2010,1648473,2504790,2230722,1385108,448730,81751523
2015,1644518,2636735,2339150,1455444,476558,8550405
```

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)
```

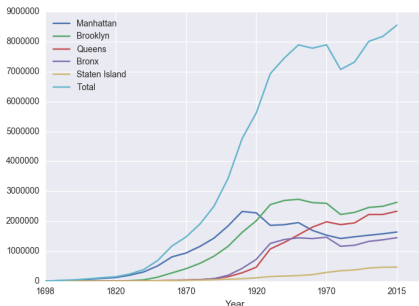
```
pop.plot(x="Year")
plt.show()
```

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
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1920,2284103,2018256,469042,732016,116531,5620048
1930,1867312,2560451,1079129,1265598,159346,6090446
1940,1889924,2698285,1297634,1394711,174441,7454995
1950,1940101,2738275,1505049,1452177,291559,7892957
1960,1698281,2627319,1809578,1624815,221993,7781984
1970,1539233,2602012,1986473,1471701,295443,7094862
1980,1428285,2210936,1801325,1164872,352121,7071439
1990,1487536,2300644,1951598,1203789,378977,7322564
2000,1537195,2465326,2229379,1326450,443728,8006278
2010,1494873,2504760,2230722,1385108,468730,8175123
2015,1644518,2636735,2339155,1455444,476558,8550405
```

nycHistPop.csv

In Lab 6



Week 7: functions

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

```
#Name: your name here
#Date: October 2017
#This program, uses functions,
#    says hello to the world!

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

if __name__ == "__main__":
    main()
```

Week 7: functions

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#This program, uses functions,  
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- Many languages require that all code must be organized with functions.

Week 7: functions

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Week 7: functions

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- You **call** or **invoke** a function by typing its name, followed by any inputs, surrounded by parenthesis:

Week 7: functions

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Example: `print("Hello", "World")`

Week 7: functions

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Example: `print("Hello", "World")`
- Can write, or **define** your own functions,

Week 7: functions

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- Functions are a way to break code into pieces, that can be easily reused.
- Many languages require that all code must be organized with functions.
- The opening function is often called `main()`
- You **call** or **invoke** a function by typing its name, followed by any inputs, surrounded by parenthesis: Example: `print("Hello", "World")`
- Can write, or **define** your own functions, which are stored, until invoked or called.

Week 8: function parameters, github

- Functions can have **input parameters**.

```
def totalWithTax(food,tip):  
    total = 0  
    tax = 0.0875  
    total = food + food * tax  
    total = total + tip  
    return(total)  
  
lunch = float(input('Enter lunch total: '))  
lTip = float(input('Enter lunch tip: '))  
lTotal = totalWithTax(lunch, lTip)  
print('Lunch total is', lTotal)  
  
dinner= float(input('Enter dinner total: '))  
dTip = float(input('Enter dinner tip: '))  
dTotal = totalWithTax(dinner, dTip)  
print('Dinner total is', dTotal)
```

Week 8: function parameters, github

- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).

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- The “placeholders” in the function definition: **formal parameters**.

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Week 8: function parameters, github

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- Functions can have **input parameters**.
- Surrounded by parenthesis, both in the function definition, and in the function call (invocation).
- The “placeholders” in the function definition: **formal parameters**.
- The ones in the function call: **actual parameters**

Week 8: function parameters, github

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- The “placeholders” in the function definition: **formal parameters**.
- The ones in the function call: **actual parameters**
- Functions can also **return values** to where it was called.

Week 8: function parameters, github

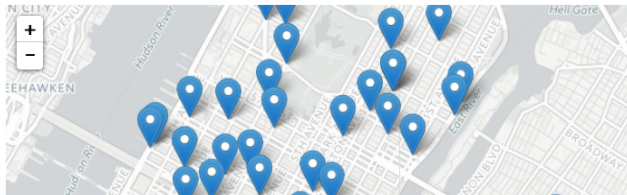
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Formal Parameters

Actual Parameters

- Functions can have **input parameters**.
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- The “placeholders” in the function definition: **formal parameters**.
- The ones in the function call: **actual parameters**.
- Functions can also **return values** to where it was called.

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)
    a = random.randrange(0,360,90)
    trey.right(a)
```

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

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- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.
- Very useful for checking user input for correctness.

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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.`

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```

- Indefinite (while) loops allow you to repeat a block of code as long as a condition holds.
- Very useful for checking user input for correctness.
- Python's built-in random package has useful methods for generating random whole numbers and real numbers.
- To use, must include:
`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/hashtes 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`

Lecture Quiz

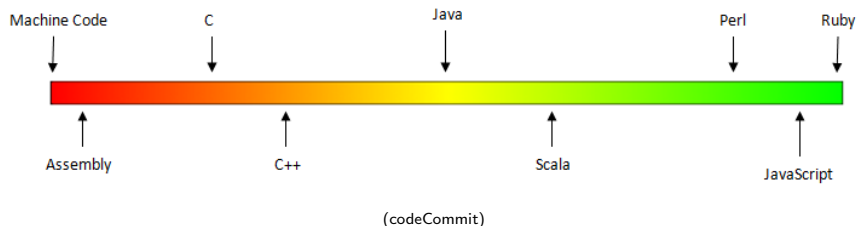
- Log-in to Gradescope
- Find LECTURE 11 Quiz
- Take the quiz
- **You have 3 minutes**

Today's Topics



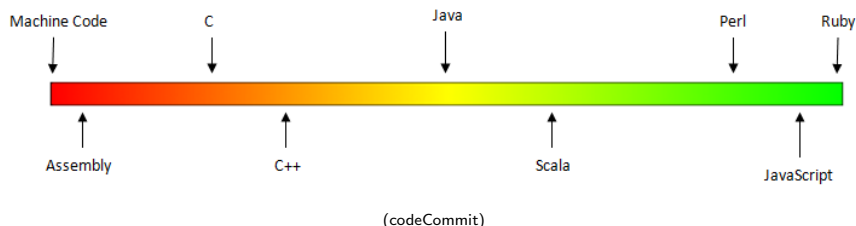
- Design Patterns: Searching
- Python Recap
- **Machine Language**
- Machine Language: Jumps & Loops
- Binary & Hex Arithmetic
- Final Exam: Format

Low-Level vs. High-Level Languages



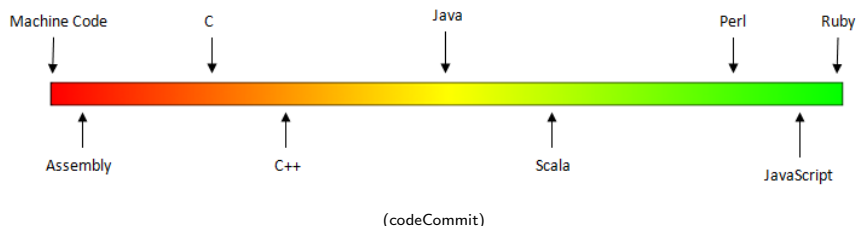
- Can view programming languages on a continuum.

Low-Level vs. High-Level Languages



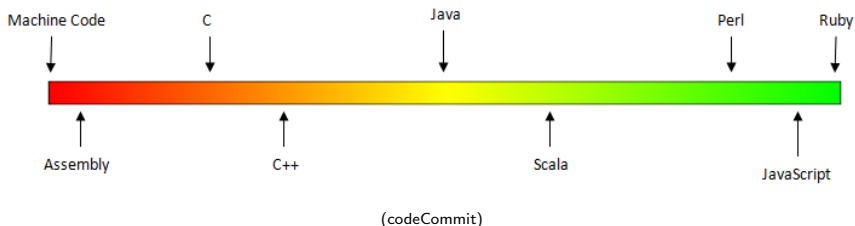
- Can view programming languages on a continuum.
- Those that directly access machine instructions & memory and have little abstraction are **low-level languages**

Low-Level vs. High-Level Languages



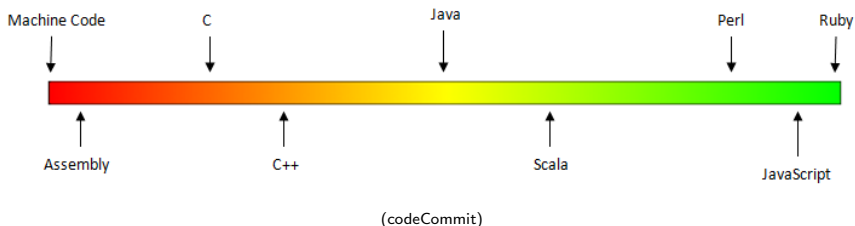
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Low-Level vs. High-Level Languages



- 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**.

Low-Level vs. 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.

Processing



Dies ist ein Blindtext. An ihm lässt sich vieles über die Schrift ablesen, in der er gesetzt ist. Auf den ersten Blick wird der Grauwert der Schriftfläche sichtbar. Dann kann man prüfen, wie gut die Schrift zu lesen ist und wie sie auf den Leser wirkt. Dies ist ein Blindtext. An ihm lässt sich

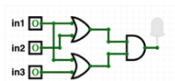


```
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    total = food * tax
    total = total + tip
    return(total)
```

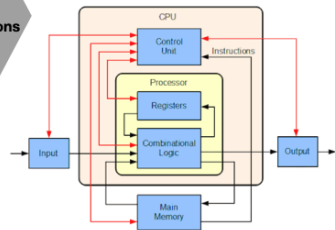
**Data
&
Instructions**



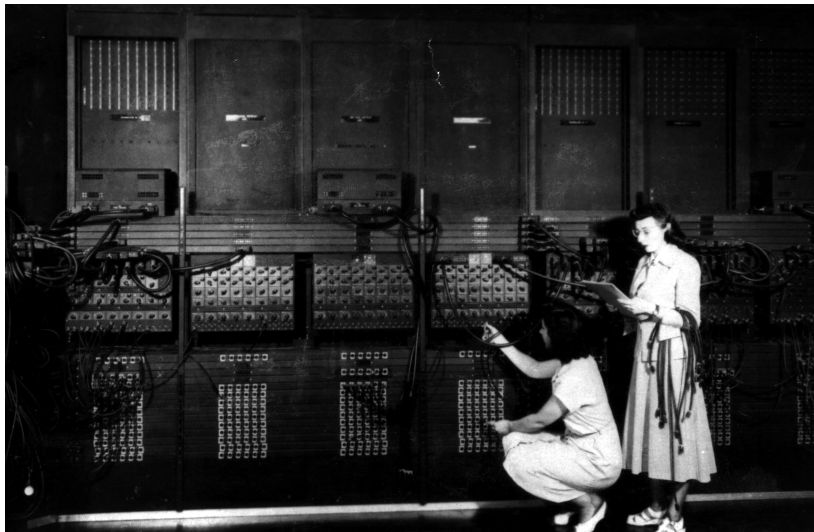
**Data
&
Instructions**



Circuits (switches)
On/Off 1/0 Logic
Billions of switches/bits



Machine Language



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

Machine Language

```
1 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 NUmxDI2C .A .X .Y SP DP DB
; 00 E012 00110000 0000 0000 0002 CFFF 0000 00
g 2000

BREAK

PB PC NUmxDI2C .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.

```
002000 c2 30      REP #30
a 002002 10      CLC
a 002003 f0      SED
a 002004 40 34 12  LSH #1234
a 002007 60 21 43  RLC #4321
a 002008 0f 83 7f 01 STA #17f83
a 00200c 00      CLD
a 00200f e2 30      SEP #30
a 002011 00      BRK
a 2012

P PC MEm013C A X Y SP BP IB
: 00 2012 00110000 0000 0000 0002 C7FF 0000 00
S 2000

BREAK
P PC MEm013C A X Y SP BP IB
: 00 2013 00110000 5555 0000 0002 C7FF 0000 00
n 1149 7193
000005 55 55 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

(wiki)

Machine Language

```
002000 C2 30 REP #30
002002 J0 CLC
002003 F0 SED
002004 40 34 12 LSH #1234
002007 60 21 43 RSC #04321
00200A 0F 83 7F 01 STA #017F83
00200E 00 CLD
00200F E2 30 SEP #30
002011 00 BRK
002012

P PC Mnemonic A X Y Z SP BP IB
: 00 E012 0010000 0000 0000 0002 C7FF 0000 00
S 2000

BREAK
P PC Mnemonic A X Y Z SP BP IB
: 00 2013 0010000 5555 0000 0002 C7FF 0000 00
n 7183 7183
00FFES 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.

Machine Language

```
002000 c2 30 REP #30
002002 10 CLC
002003 F0 SED
002004 40 34 12 LSH #1234
002007 60 21 43 RSC #4321
00200A 0F 83 7F 01 STA #17F83
00200E 30 CLD
00200F E2 30 SEP #30
002011 00 BRK
002012

P PC Mmn013C A X Y SP BP IB
: 00 E012 0010000 0000 0000 0002 C7FF 0000 00
S 2000


BREAK

P PC Mmn013C A X Y SP BP IB
: 00 2013 0010000 5555 0000 0002 C7FF 0000 00
n 1149 7193
00FF55 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.

Machine Language



The screenshot shows a WeMIPS emulator window. The top section displays assembly instructions with their corresponding hexadecimal and decimal values. The bottom section shows the current state of the processor registers (PC, PC, MIPS, A, X, Y, SP, BP, B0) and a memory dump.

```
002000 C2 30 REP #30
002002 J0 CLC
002003 F0 SED
002004 40 34 12 LSH #1234
002007 60 21 43 RLC #04321
00200A 0F 83 7F 01 STA #017F83
00200E 30 CLD
00200F E2 30 SEP #30
002011 00 BRK
002012

PC PC MIPS A X Y SP BP B0
: 00 2012 0010000 0000 0000 0002 C7FF 0000 00
$ 2000

BREAK

PC PC MIPS A X Y SP BP B0
: 00 2013 0010000 5555 0000 0002 C7FF 0000 00
n 1149 7193
00FF55 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.
- 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 # 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
32 syscall # print to the log
```

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

(WeMIPS)

WeMIPS

Line 3
Out
Show/Hide Deltas
User Guide | Unit Tests | Docs

[Addition Doubler](#)
[Stop](#)
[Looper](#)
[Stack Test](#)
[Hello World](#)

[Code Gen Save Setting](#)
[Interactive](#)
[Binary2 Decimal](#)
[Decimal2 Binary](#)

[Debug](#)

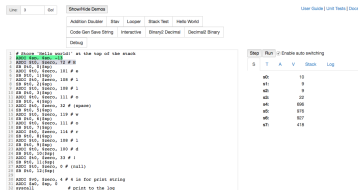
Step	Run	Enable auto switching
S	T	A V Stack Log
		10
ef:		9
ef:		9
ef:		22
ef:		892
ef:		976
ef:		927
ef:		418

```

1 # Store 'Hello world' at the top of the stack
2 ADDI $a0, $zero, 10
3 ADDI $k0, $zero, 12 # $H
4 CD $k0, 0($a0)
5 ADDI $t0, $zero, 101 # e
6 CD $t0, 1($a0)
7 ADDI $t0, $zero, 108 # l
8 CD $t0, 2($a0)
9 ADDI $t0, $zero, 109 # l
10 CD $t0, 3($a0)
11 ADDI $t0, $zero, 111 # o
12 CD $t0, 4($a0)
13 ADDI $t0, $zero, 32 # (space)
14 CD $t0, 5($a0)
15 ADDI $t0, $zero, 119 # d
16 CD $t0, 6($a0)
17 ADDI $t0, $zero, 111 # o
18 CD $t0, 7($a0)
19 ADDI $t0, $zero, 114 # r
20 CD $t0, 8($a0)
21 ADDI $t0, $zero, 108 # l
22 CD $t0, 9($a0)
23 ADDI $t0, $zero, 109 # d
24 CD $t0, 10($a0)
25 ADDI $t0, $zero, 33 # !
26 ADDI $t0, $zero, 0 # (null)
27 CD $t0, 11($a0)
28 ADDI $v0, $zero, 4 # 4 in for print string
29 ADDI $a0, $a0, 0
30 syscall
31 # print to the log
  
```

(Demo with WeMIPS)

MIPS Commands



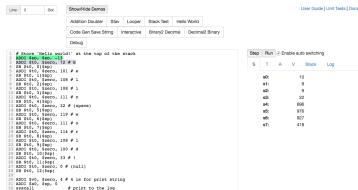
The screenshot shows the MIPS simulator interface. At the top, there are tabs for 'User Guide', 'Unit Tests', and 'Docs'. Below these are buttons for 'Show/Hide Demos', 'Assembler', 'Debugger', 'Stack Test', and 'Hello World'. A dropdown menu is open, showing options: 'Code Gen: Data String', 'Interactive', 'Binary/Decimal', and 'Decimal/Binary'. The main window displays assembly code with line numbers 1 through 33. The code includes comments and instructions for loading, adding, and storing data. On the right, there is a 'Registers' window with a table showing the values of registers \$0 through \$31. The 'Stop' button is highlighted, and the 'Run' button is disabled.

```
1 # MIPS "Hello world" at the top of the stack
2 ADDUI $0, $0, 0
3 LA $0, 0
4 ADDUI $0, $0, 10
5 LA $0, 0
6 ADDUI $0, $0, 100
7 LA $0, 0
8 ADDUI $0, $0, 100
9 LA $0, 0
10 ADDUI $0, $0, 100
11 LA $0, 0
12 ADDUI $0, $0, 100
13 LA $0, 0
14 ADDUI $0, $0, 100
15 LA $0, 0
16 ADDUI $0, $0, 100
17 LA $0, 0
18 ADDUI $0, $0, 100
19 LA $0, 0
20 ADDUI $0, $0, 100
21 LA $0, 0
22 ADDUI $0, $0, 100
23 LA $0, 0
24 ADDUI $0, $0, 100
25 LA $0, 0
26 ADDUI $0, $0, 100
27 LA $0, 0
28 ADDUI $0, $0, 100
29 LA $0, 0
30 ADDUI $0, $0, 100
31 LA $0, 0
32 ADDUI $0, $0, 100
33 # print to the log
```

Register	Value
\$0	0
\$1	0
\$2	0
\$3	0
\$4	0
\$5	0
\$6	0
\$7	0
\$8	0
\$9	0
\$10	0
\$11	0
\$12	0
\$13	0
\$14	0
\$15	0
\$16	0
\$17	0
\$18	0
\$19	0
\$20	0
\$21	0
\$22	0
\$23	0
\$24	0
\$25	0
\$26	0
\$27	0
\$28	0
\$29	0
\$30	0
\$31	0

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

MIPS Commands



- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...

MIPS Commands

[illegible]

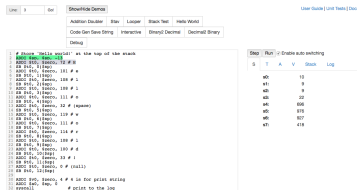
- **Registers:** locations for storing information that can be quickly accessed. Names start with '\$': \$s0, \$s1, \$t0, \$t1,...
- **R Instructions:** Commands that use data in the registers:

MIPS Commands

[illegible]

- **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 the MIPS simulator interface. On the left, there's a text area with assembly code. On the right, there's a register window showing the state of registers \$0 through \$7.

```
# Please "Hello world" at the top of the window
1 addi $v0, $zero, 10 # $0
2 syscall
3 # $v0 = 10
4 # $v0 = 10
5 # $v0 = 10
6 # $v0 = 10
7 # $v0 = 10
8 # $v0 = 10
9 # $v0 = 10
10 # $v0 = 10
11 # $v0 = 10
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27 # $v0 = 10
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29 # $v0 = 10
30 # $v0 = 10
31 # $v0 = 10
32 # $v0 = 10
33 # $v0 = 10
34 # $v0 = 10
35 # $v0 = 10
36 # $v0 = 10
37 # $v0 = 10
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41 # $v0 = 10
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94 # $v0 = 10
95 # $v0 = 10
96 # $v0 = 10
97 # $v0 = 10
98 # $v0 = 10
99 # $v0 = 10
100 # $v0 = 10
```

Register	Value
\$0	0
\$1	0
\$2	0
\$3	0
\$4	0
\$5	0
\$6	0
\$7	0

- **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.

MIPS Commands

Line 9

Get

SourceCode

[Addition Double](#)
[Euler](#)
[Leap](#)
[Stack Test](#)
[Hello World](#)

Code Gen Save Editor

Interactive

Dynamic

Decimal

Binary

Debug

Step

Run

Enable auto switching

S

T

A

V

Stack

Log

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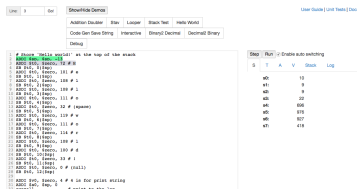
435

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437

- **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



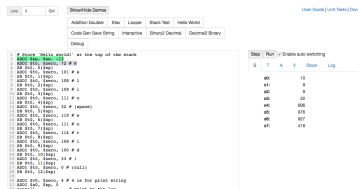
The screenshot shows the MIPS simulator interface. The top bar includes 'File', 'Edit', and 'Show/Hide Demos'. Below this is a toolbar with buttons for 'Address Disabler', 'Stop', 'Log', 'Stack Test', and 'Help Window'. A dropdown menu is open, showing options: 'Code Gen Data String', 'Interactive', 'Binary', 'Decimal', and 'Octal/Binary'. The main window displays assembly code with line numbers 1 through 30. The code includes comments and instructions like 'addi \$s0, \$zero, 10', 'add \$s1, \$s0, \$s2', 'addi \$s1, \$s2, 100', and 'j \$s1, 1000000'. On the right, the 'Registers' window is visible, showing a table of registers \$0 through \$31 with their current values.

```
1 # MIPS "Hello World" at the top of the stack
2 addi $s0, $zero, 10
3 add $s1, $s0, $s2
4 addi $s1, $s2, 100
5 addi $s1, $s2, 100
6 addi $s1, $s2, 100
7 addi $s1, $s2, 100
8 addi $s1, $s2, 100
9 addi $s1, $s2, 100
10 addi $s1, $s2, 100
11 addi $s1, $s2, 100
12 addi $s1, $s2, 100
13 addi $s1, $s2, 100
14 addi $s1, $s2, 100
15 addi $s1, $s2, 100
16 addi $s1, $s2, 100
17 addi $s1, $s2, 100
18 addi $s1, $s2, 100
19 addi $s1, $s2, 100
20 addi $s1, $s2, 100
21 addi $s1, $s2, 100
22 addi $s1, $s2, 100
23 addi $s1, $s2, 100
24 addi $s1, $s2, 100
25 addi $s1, $s2, 100
26 addi $s1, $s2, 100
27 addi $s1, $s2, 100
28 addi $s1, $s2, 100
29 addi $s1, $s2, 100
30 addi $s1, $s2, 100
```

Register	Value
\$0	0
\$1	10
\$2	0
\$3	0
\$4	0
\$5	0
\$6	0
\$7	0

- **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 immediate values.
addi \$s1, \$s2, 100 (Basic form: OP rd, rs, imm)
- **J Instructions:** instructions that jump to another memory location.

MIPS Commands

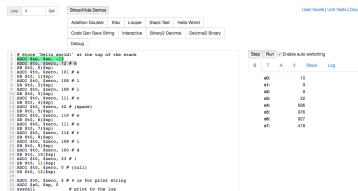


```
1 # Prints "Hello world!" at the top of the window
2 addi $v0, $zero, 10 # $v0
3 add $a0, $zero
4 addi $v0, $zero, 10 # $v0
5 add $a0, $zero
6 addi $v0, $zero, 10 # $v0
7 add $a0, $zero
8 addi $v0, $zero, 10 # $v0
9 add $a0, $zero
10 addi $v0, $zero, 10 # $v0
11 add $a0, $zero
12 addi $v0, $zero, 10 # $v0
13 add $a0, $zero
14 addi $v0, $zero, 10 # $v0
15 add $a0, $zero
16 addi $v0, $zero, 10 # $v0
17 add $a0, $zero
18 addi $v0, $zero, 10 # $v0
19 add $a0, $zero
20 addi $v0, $zero, 10 # $v0
21 add $a0, $zero
22 addi $v0, $zero, 10 # $v0
23 add $a0, $zero
24 addi $v0, $zero, 10 # $v0
25 add $a0, $zero
26 addi $v0, $zero, 10 # $v0
27 add $a0, $zero
28 addi $v0, $zero, 10 # $v0
29 add $a0, $zero
30 addi $v0, $zero, 10 # $v0
```

\$	T	A	V	Stack	Log
\$0					
\$1					
\$2					
\$3					
\$4					
\$5					
\$6					
\$7					

- **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.
j done

MIPS Commands



```
1 # Please "Hello world" at the top of the window
2 addi $v0, $zero, 10 # $0
3 add $a0, $zero
4 addi $v0, $zero, 10 # $0
5 add $a0, $zero
6 addi $v0, $zero, 10 # $0
7 add $a0, $zero
8 addi $v0, $zero, 10 # $0
9 add $a0, $zero
10 addi $v0, $zero, 10 # $0
11 add $a0, $zero
12 addi $v0, $zero, 10 # $0
13 add $a0, $zero
14 addi $v0, $zero, 10 # $0
15 add $a0, $zero
16 addi $v0, $zero, 10 # $0
17 add $a0, $zero
18 addi $v0, $zero, 10 # $0
19 add $a0, $zero
20 addi $v0, $zero, 10 # $0
21 add $a0, $zero
22 addi $v0, $zero, 10 # $0
23 add $a0, $zero
24 addi $v0, $zero, 10 # $0
25 add $a0, $zero
26 addi $v0, $zero, 10 # $0
27 add $a0, $zero
28 addi $v0, $zero, 10 # $0
29 add $a0, $zero
30 addi $v0, $zero, 10 # $0
```

- **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.
j done (Basic form: OP label)

Challenge:

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
32 syscall # print to the log
```

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

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

Addition Doubler
Shw
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 ASCII Strcpy strcpy
3 ASCII Strcpy, strcpy, 72 # W
4 CD Str, 0 (page)
5 ASCII Str, strcpy, 101 # w
6 CD Str, 1 (page)
7 ASCII Str, strcpy, 108 # l
8 CD Str, 2 (page)
9 ASCII Str, strcpy, 108 # l
10 CD Str, 3 (page)
11 ASCII Str, strcpy, 111 # i
12 CD Str, 4 (page)
13 ASCII Str, strcpy, 32 # (space)
14 CD Str, 5 (page)
15 ASCII Str, strcpy, 119 # w
16 CD Str, 6 (page)
17 ASCII Str, strcpy, 111 # o
18 CD Str, 7 (page)
19 ASCII Str, strcpy, 114 # r
20 CD Str, 8 (page)
21 ASCII Str, strcpy, 108 # l
22 ASCII Str, strcpy, 108 # l
23 ASCII Str, strcpy, 105 # d
24 ASCII Str, strcpy, 111 # l
25 ASCII Str, strcpy, 33 # !
26 CD Str, 1 (page)
27 ASCII Str, strcpy, 0 # (null)
28 CD Str, 12 (page)
29
30 ASCII Str, strcpy, 4 # i in for print string
31 ASCII Str, strcpy, 0
32 printf
          
```

Step	Run	Enable auto switching
S	T	A V Stack Log
		10
str:		9
str:		9
str:		22
str:		350
str:		976
str:		927
str:		418

(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.



The screenshot shows a debugger window with two panes. The left pane displays assembly code with instructions like `movl $0, %eax`, `movl $1, %ecx`, and `jmp $0x00000000`. The right pane shows the state of registers, including `%eax` containing 0 and `%ecx` containing 1.

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.
- Can indicate locations by writing **labels** at the beginning of a line.

The screenshot shows the RStudio interface. The top menu bar includes 'Session', 'Help', and 'RStudio'. The top toolbar contains icons for 'Author/Viewer', 'File', 'Edit', 'Source', 'Run', 'Help', 'View', 'Tools', 'Session', 'Environment', 'Recent Files', 'Recent Packages', and 'Recent Plots'. The main editor window displays the following R code:

```
## Linear regression model
##
## Fit a linear regression model to the data
##
## The data is stored in a data frame called 'data'
##
## The response variable is 'y'
##
## The predictor variable is 'x'
##
## Fit the model
##
## Print the summary of the model
```

The console window on the right shows the output of the model fitting process:

```
## Fit a linear regression model to the data
##
## The data is stored in a data frame called 'data'
##
## The response variable is 'y'
##
## The predictor variable is 'x'
##
## Fit the model
##
## Print the summary of the model
```

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.
- Can indicate locations by writing **labels** at the beginning of a line.
- Then give a command to jump to that location.



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- Different kinds of jumps:
 - ▶ **Unconditional:** `j Done` will jump to the address with label `Done`.
 - ▶ **Branch if Equal:** `beq $s0 $s1 DoAgain` will jump to the address with label `DoAgain` if the registers `$s0` and `$s1` contain the same value.



Loops & Jumps in Machine Language

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 - ▶ See reading for more variations.



Jump Demo

Line: 18 Go!

Show/Hide Demos

[User Guide](#) | [Unit Tests](#) | [Docs](#)

```
1
2 ADDI $sp, $sp, -27      # Set up stack
3 ADDI $s3, $zero, 1      # Store 1 in a register
4 ADDI $t0, $zero, 97     # Set $t0 at 97 (a)
5 ADDI $s2, $zero, 26     # Use to test when you reach 26
6 SETUP: SB $t0, 0($sp)   # Next letter in $t0
7 ADDI $sp, $sp, 1        # Increment the stack
8 SUB $s2, $s2, $s3       # Decrease the counter by 1
9 ADDI $t0, $t0, 1        # Increment the letter
10 BEQ $s2, $zero, DONE   # Jump to done if $s2 == 0
11 J SETUP                # Else, jump back to SETUP
12 DONE: ADDI $t0, $zero, 0 # Null (0) to terminate string
13 SB $t0, 0($sp)         # Add null to stack
14 ADDI $sp, $sp, -26     # Set up stack to print
15 ADDI $v0, $zero, 4      # 4 is for print string
16 ADDI $a0, $sp, 0       # Set $a0 to stack pointer
17 syscall                # Print to the log
```

(Demo
with
WeMIPS)

Step **Run** ☒ Enable auto switching

S T A V Stack Log

Clear Log

Emulation complete, returning to line 1

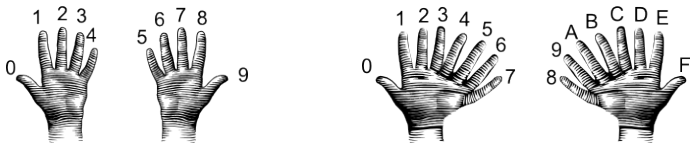
abcdefghijklmnopqrstuvwxyz

Today's Topics



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- Machine Language: Jumps & Loops
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- Final Exam: Format

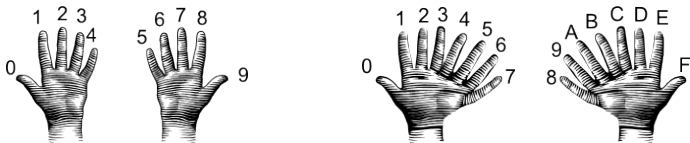
Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

- From hexadecimal to decimal (assuming two-digit numbers):
 - ▶ Convert first digit to decimal and multiple by 16.

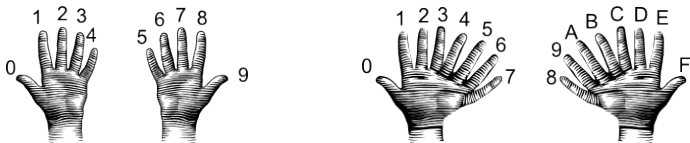
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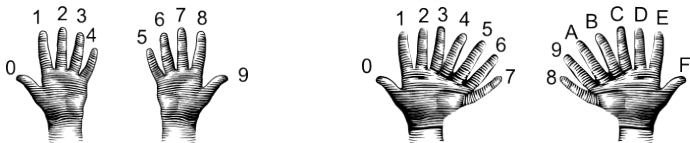
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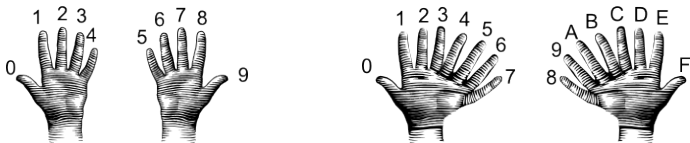
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2 in decimal is 2.

Hexadecimal to Decimal: Converting Between Bases



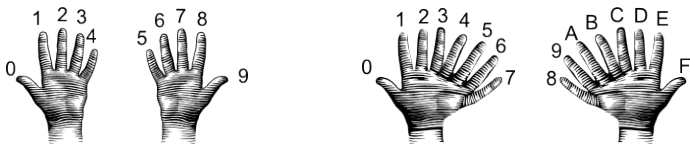
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Hexadecimal to Decimal: Converting Between Bases



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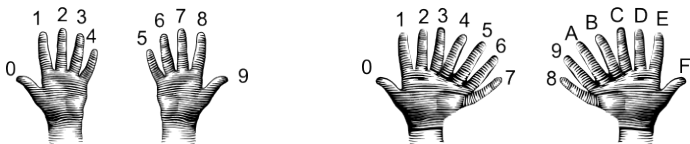
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2 in decimal is 2. 2×16 is 32.

A in decimal digits is 10.

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

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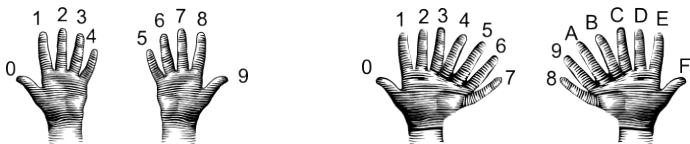
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2 in decimal is 2. 2×16 is 32.

A in decimal digits is 10.

$32 + 10$ is 42.

Hexadecimal to Decimal: Converting Between Bases



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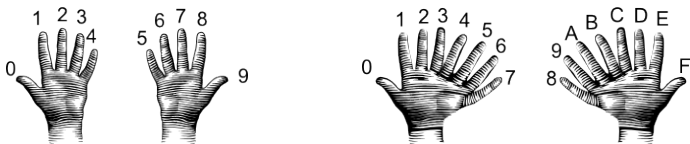
A in decimal digits is 10.

$32 + 10$ is 42.

Answer is 42.

- ▶ Example: what is 99 as a decimal number?

Hexadecimal to Decimal: Converting Between Bases



(from i-programmer.info)

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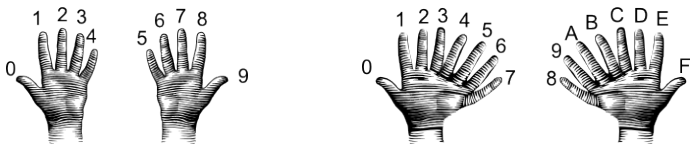
$32 + 10$ is 42.

Answer is 42.

- ▶ Example: what is 99 as a decimal number?

9 in decimal is 9.

Hexadecimal to Decimal: Converting Between Bases



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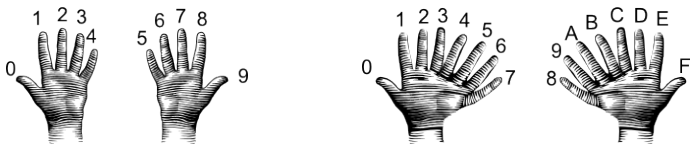
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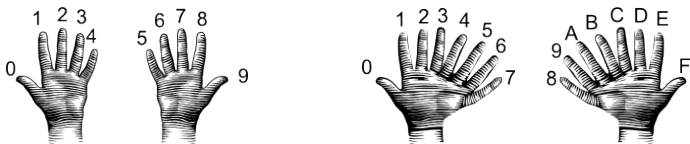
Answer is 42.

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9 in decimal digits is 9

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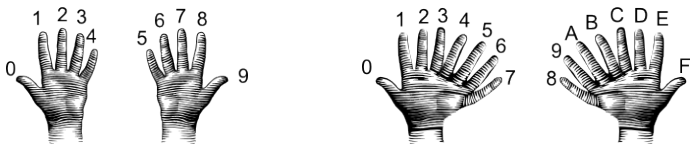
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9 in decimal digits is 9

$144 + 9$ is 153.

Hexadecimal to Decimal: Converting Between Bases



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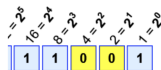
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9 in decimal digits is 9

$144 + 9$ is 153.

Answer is 153.

Decimal to Binary: Converting Between Bases

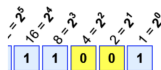


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- From decimal to binary:

- Divide by 128 ($= 2^7$). Quotient is the first digit.

Decimal to Binary: Converting Between Bases

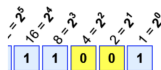


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Decimal to Binary: Converting Between Bases

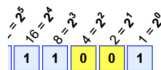
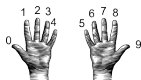


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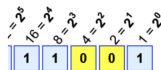


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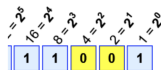


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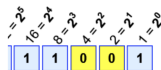


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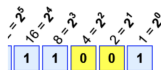


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- ▶ Divide remainder by 2 ($= 2^1$). Quotient is the next digit.

Decimal to Binary: Converting Between Bases

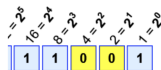


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Decimal to Binary: Converting Between Bases



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Decimal to Binary: Converting Between Bases



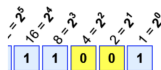
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130/128 is 1 rem 2.

Decimal to Binary: Converting Between Bases



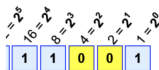
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- ▶ Example: what is 130 in binary notation?

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

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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- ▶ Example: what is 130 in binary notation?
130/128 is 1 rem 2. First digit is 1: 1...
2/64 is 0 rem 2.

Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

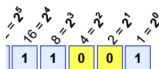
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Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

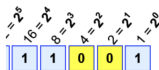
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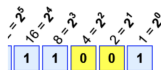
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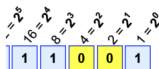
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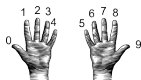
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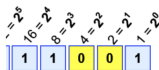
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Decimal to Binary: Converting Between Bases



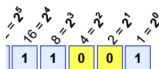
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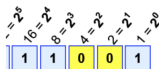
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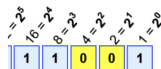
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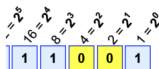
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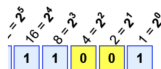
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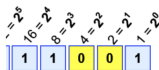
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Decimal to Binary: Converting Between Bases



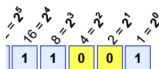
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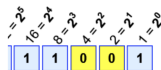
2/8 is 0 rem 2. Next digit is 0: 10000...

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

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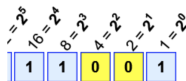
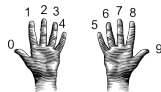
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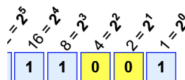
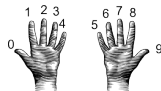
Decimal to Binary: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: what is 99 in binary notation?

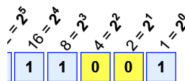
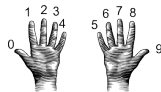
Decimal to Binary: Converting Between Bases



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- Example: what is 99 in binary notation?
99/128 is 0 rem 99.

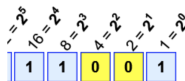
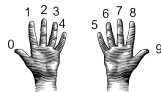
Decimal to Binary: Converting Between Bases



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- Example: what is 99 in binary notation?
99/128 is 0 rem 99. First digit is 0:

Decimal to Binary: Converting Between Bases



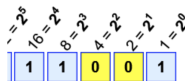
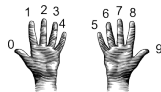
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99/64 is 1 rem 35.

Decimal to Binary: Converting Between Bases



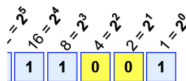
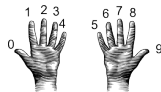
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Decimal to Binary: Converting Between Bases



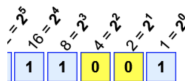
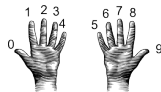
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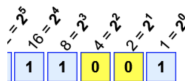
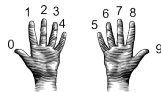
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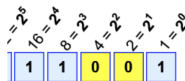
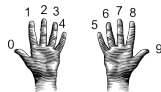
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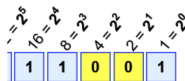
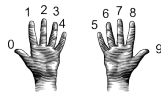
- Example: what is 99 in binary notation?

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



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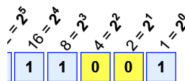
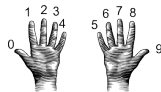
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Decimal to Binary: Converting Between Bases



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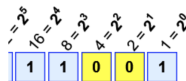
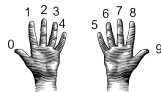
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Decimal to Binary: Converting Between Bases



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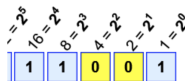
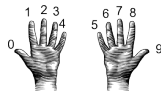
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Decimal to Binary: Converting Between Bases



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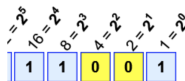
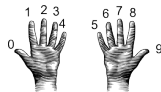
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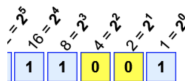
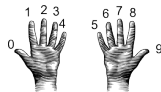
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Decimal to Binary: Converting Between Bases

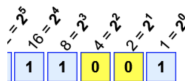
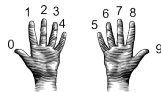


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Decimal to Binary: Converting Between Bases

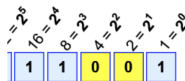
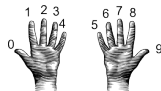


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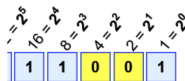
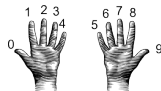
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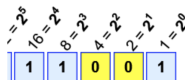
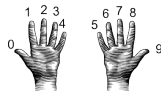
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3/8 is 0 rem 3. Next digit is 0: 01100...

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Decimal to Binary: Converting Between Bases

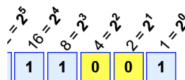
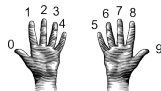


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3/4 is 0 remainder 3. Next digit is 0: 011000...
3/2 is 1 rem 1.

Decimal to Binary: Converting Between Bases

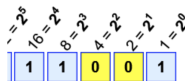
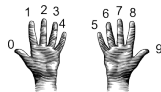


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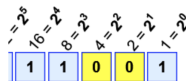
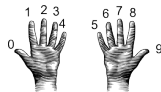


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3/4 is 0 remainder 3. Next digit is 0:	011000...
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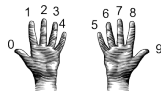


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3/8 is 0 rem 3. Next digit is 0:	01100...
3/4 is 0 remainder 3. Next digit is 0:	011000...
3/2 is 1 rem 1. Next digit is 1:	0110001...
Adding the last remainder:	01100011

Decimal to Binary: Converting Between Bases



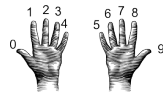
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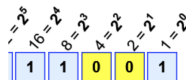
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3/4 is 0 remainder 3. Next digit is 0:	011000...
3/2 is 1 rem 1. Next digit is 1:	0110001...
Adding the last remainder:	01100011

Answer is 1100011.

Binary to Decimal: Converting Between Bases

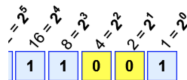
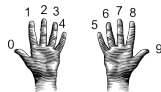


- From binary to decimal:
 - Set sum = last digit.



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Binary to Decimal: Converting Between Bases

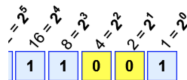
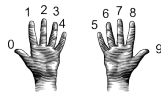


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

● From binary to decimal:

- ▶ Set sum = last digit.
- ▶ Multiply next digit by $2 = 2^1$. Add to sum.

Binary to Decimal: Converting Between Bases

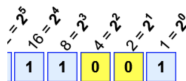
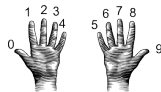


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● From binary to decimal:

- ▶ Set sum = last digit.
- ▶ Multiply next digit by $2 = 2^1$. Add to sum.
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Binary to Decimal: Converting Between Bases

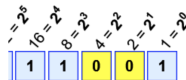
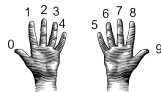


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Binary to Decimal: Converting Between Bases

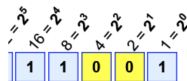
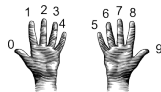


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- ▶ Multiply next digit by $16 = 2^4$. Add to sum.

Binary to Decimal: Converting Between Bases

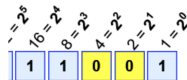
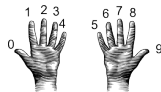


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- ▶ Multiply next digit by $32 = 2^5$. Add to sum.

Binary to Decimal: Converting Between Bases

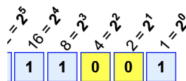
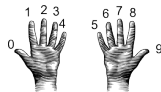


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- ▶ Multiply next digit by $16 = 2^4$. Add to sum.
- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.

Binary to Decimal: Converting Between Bases

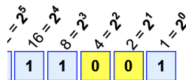
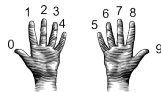


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- ▶ Multiply next digit by $16 = 2^4$. Add to sum.
- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.

Binary to Decimal: Converting Between Bases

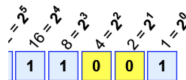
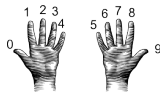


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- ▶ Multiply next digit by $4 = 2^2$. Add to sum.
- ▶ Multiply next digit by $8 = 2^3$. Add to sum.
- ▶ Multiply next digit by $16 = 2^4$. Add to sum.
- ▶ Multiply next digit by $32 = 2^5$. Add to sum.
- ▶ Multiply next digit by $64 = 2^6$. Add to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

Binary to Decimal: Converting Between Bases



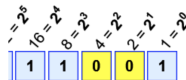
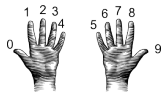
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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- ▶ 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



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

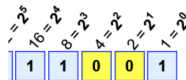
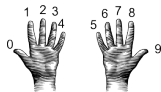
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- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1

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

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

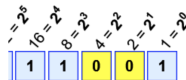
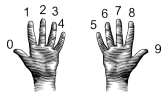
● From binary to decimal:

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- ▶ 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



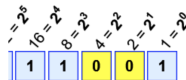
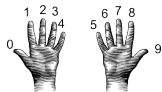
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- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1
 $1 \times 4 = 4$. Add 4 to sum:

Binary to Decimal: Converting Between Bases



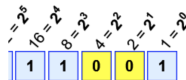
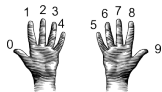
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- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

Sum starts with:	1
$0 \times 2 = 0$. Add 0 to sum:	1
$1 \times 4 = 4$. Add 4 to sum:	5

Binary to Decimal: Converting Between Bases



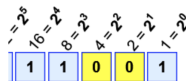
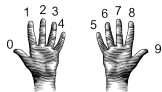
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Sum starts with:	1
$0 \times 2 = 0$. Add 0 to sum:	1
$1 \times 4 = 4$. Add 4 to sum:	5
$1 \times 8 = 8$. Add 8 to sum:	

Binary to Decimal: Converting Between Bases



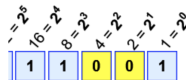
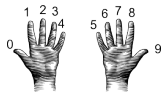
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- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
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- ▶ Example: What is 111101 in decimal?

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

Binary to Decimal: Converting Between Bases



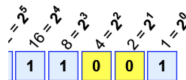
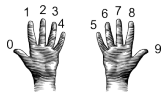
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Sum starts with: 1
 $0 \times 2 = 0$. Add 0 to sum: 1
 $1 \times 4 = 4$. Add 4 to sum: 5
 $1 \times 8 = 8$. Add 8 to sum: 13
 $1 \times 16 = 16$. Add 16 to sum:

Binary to Decimal: Converting Between Bases



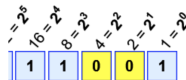
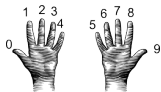
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- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

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

Binary to Decimal: Converting Between Bases



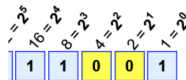
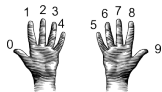
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- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
- ▶ Multiply next digit by $128 = 2^7$. Add to sum.
- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

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

Binary to Decimal: Converting Between Bases



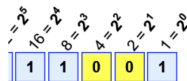
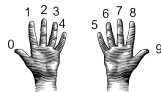
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- ▶ Multiply next digit by $64 = 2^6$. Add to sum.
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- ▶ Sum is the decimal number.
- ▶ Example: What is 111101 in decimal?

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

Binary to Decimal: Converting Between Bases



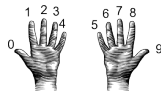
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- ▶ Example: What is 111101 in decimal?

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$1 \times 4 = 4$. Add 4 to sum:	5
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Binary to Decimal: Converting Between Bases

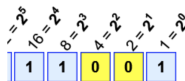
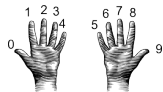


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with:

Binary to Decimal: Converting Between Bases



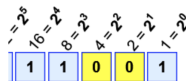
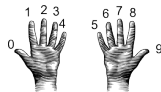
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with: 0

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

Binary to Decimal: Converting Between Bases



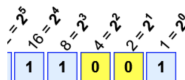
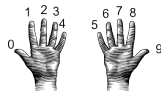
Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

Sum starts with: 0

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

Binary to Decimal: Converting Between Bases



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

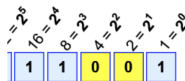
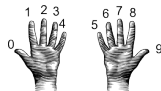
- Example: What is 10100100 in decimal?

Sum starts with: 0

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

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

Binary to Decimal: Converting Between Bases



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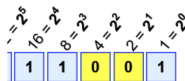
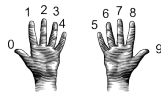
- Example: What is 10100100 in decimal?

Sum starts with: 0

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

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

Binary to Decimal: Converting Between Bases



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- Example: What is 10100100 in decimal?

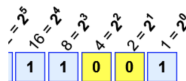
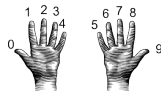
Sum starts with: 0

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

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

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

Binary to Decimal: Converting Between Bases



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- Example: What is 10100100 in decimal?

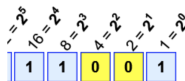
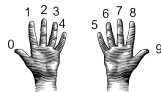
Sum starts with: 0

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

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

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

Binary to Decimal: Converting Between Bases



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- Example: What is 10100100 in decimal?

Sum starts with: 0

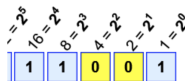
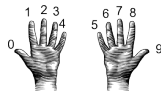
$0 \times 2 = 0$. Add 0 to sum: 0

$1 \times 4 = 4$. 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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- Example: What is 10100100 in decimal?

Sum starts with: 0

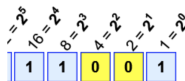
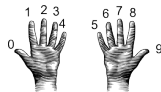
$0 \times 2 = 0$. Add 0 to sum: 0

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

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

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

Binary to Decimal: Converting Between Bases



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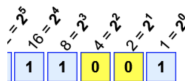
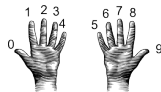
$1 \times 4 = 4$. Add 4 to sum: 4

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

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

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

Binary to Decimal: Converting Between Bases

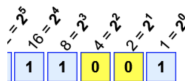
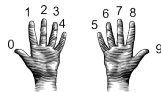


Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

- Example: What is 10100100 in decimal?

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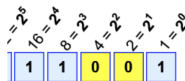
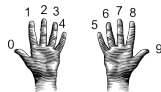


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$0 \times 64 = 0$. Add 0 to sum:	

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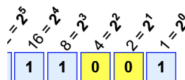
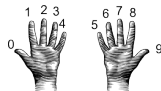


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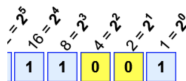
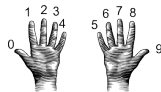


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Binary to Decimal: Converting Between Bases

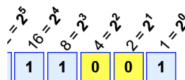
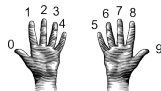


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$1 \times 128 = 128$. Add 128 to sum:	164

Binary to Decimal: Converting Between Bases



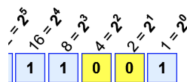
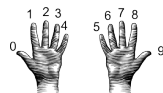
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The answer is 164.

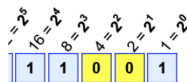
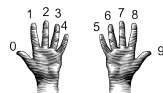
Design Challenge: Incrementers



Example: $1 \times 16 + 1 \times 8 + 1 \times 1 = 16 + 8 + 1 = 25$

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

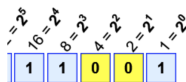
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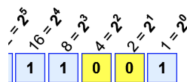


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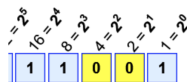


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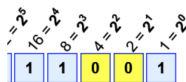
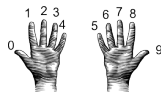
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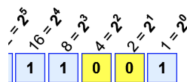
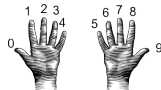
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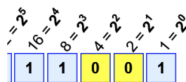
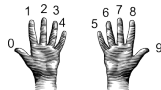


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Example: "1001" → "1010"

Recap



- Searching through data is a common task– built-in functions and standard design patterns for this.

Recap



- Searching through data is a common task– built-in functions and standard design patterns for this.
- Programming languages can be classified by the level of abstraction and direct access to data.

Today's Topics



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

Final Overview: Administration

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- The morning of the exam: log into Gradescope, find the **CSci 127 Final Exam** course and open the assignment.

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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

10 December 2020

Exam Rules

- Show all your work. Your grade will be based on the work shown.
- The exam is closed book and closed notes with the exception of one 8 1/2" x 11" piece of paper filled with notes, programs, etc.
- While taking the exam, you may have with you pens and pencils, and your note sheet.
- You may not use a computer, calculator, tablet, smart watch, or other electronic device.
- Do not open this exam until instructed to do so.

Hunter College upholds acts of academic dishonesty (i.e., plagiarism, cheating on examinations, obtaining unfair advantage, and fabrication of exams and official documents) as serious offenses against the values of intellectual integrity. The College is committed to upholding the CUNY Policy on Academic Integrity and will pursue cases of academic dishonesty according to the Hunter College Academic Integrity Procedures.

<small>If academic integrity rules of academic dishonesty will be reported to the Dean of Hunter and will result in sanctions.</small>
Name
Signature
Date
Signature

Exam Options

Exam Times:

- Default Regular Time: Monday, 24 May, 9-11am.

FINAL EXAM, VERSION 3
CSci 127: Introduction to Computer Science
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Hunter College reports acts of academic dishonesty to its plagiarism, cheating on examinations, cheating under cheating, and fabrication of papers and official documents to various offices against the rules of institutional cheating. The College is committed to, regarding the CSCI 127 Final, its Academic Integrity and will pursue cases of academic dishonesty according to the Hunter College Academic Integrity Procedures.

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

10 December 2018

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- Have all your work. Your grade will be based on the work shown.
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By submitting this page, all cases of academic dishonesty will be reported to the Dean of Hunter College and will result in sanctions.
Name:
Signature:
Date:
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FINAL EXAM, VERSION 3
CSci 127: Introduction to Computer Science
Hunter College, City University of New York

10 December 2020

Exam Rules

- Bring all your work. Your grade will be based on this work alone.
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Hunter College reports acts of academic dishonesty to its department, faculty or committees, advising, and deans, and violations of campus and official documents to various offices within the City of University of New York. The College is committed to upholding the CUNY Policy on Academic Integrity and will pursue acts of academic dishonesty according to the Hunter College Academic Integrity Procedures.

Signature of student (print name)
Name
Signature
Grade
Signature

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Hunter College reports acts of academic dishonesty to its department, advising on recommendations, advising on disciplinary action, and distribution of reports and official transcripts to various offices within the college's institutional setting. The College is committed to upholding the CUNY Policy on Academic Integrity and will pursue acts of academic dishonesty according to the Hunter College Academic Integrity Procedures.

Unauthorized use or possession of academic dishonesty will be reported to the Dean of Academic Integrity and will result in course failure.
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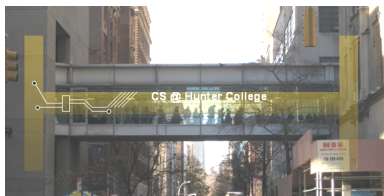
Weekly Reminders!



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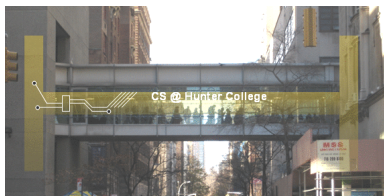
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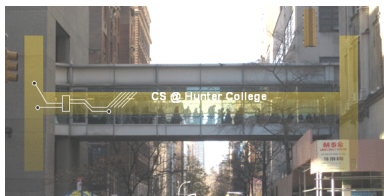
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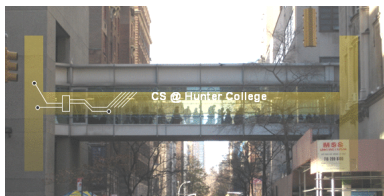
Weekly Reminders!



Before next lecture, don't forget to:

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- Take the Lecture Preview on Blackboard on Monday (or no later than 10am on Tuesday)