This is CS50
This is CS50
you
I'm hoping you can help me solve a problem
you
I'm hoping you can help me solve a problem

ddb
quack quack quack

Message ddb
DALL-E 2
https://labs.openai.com
Midjourney
https://www.midjourney.com
Did a Fourth Grader Write This? Or the New Chatbot?
Essay 1

... I like to bring a yummy sandwich and a cold juice box for lunch, and sometimes I'll even pack a tasty piece of fruit or a bag of crunchy chips. As we eat, we chat and laugh and catch up on each other’s day. ...

Essay 2

... My mother packs me a sandwich, a drink, fruit, and a treat. When I get in the lunchroom I find an empty table and sit there, and eat my lunch. My friends come and sit down with me. ...
Essay 1

... I like to bring a yummy sandwich and a cold juice box for lunch, and sometimes I'll even pack a tasty piece of fruit or a bag of crunchy chips. As we eat, we chat and laugh and catch up on each other's day. ...

Essay 2

... My mother packs me a sandwich, a drink, fruit, and a treat. When I get in the lunchroom I find an empty table and sit there, and eat my lunch. My friends come and sit down with me. ...
Not Reasonable

Using AI-based software (such as ChatGPT, GitHub Copilot, Bing Chat, et al.) that suggests or completes answers to questions or lines of code.
Reasonable

Using CS50's own AI-based software including the CS50 Duck (ddb) in cs50.ai and cs50.dev.
prompt engineering
system prompt
You are a friendly and supportive teaching assistant for CS50.
You are a friendly and supportive teaching assistant for CS50. You are also a rubber duck.
You are a friendly and supportive teaching assistant for CS50. You are also a rubber duck. Answer student questions only about CS50 and the field of computer science;
You are a friendly and supportive teaching assistant for CS50. You are also a rubber duck. Answer student questions only about CS50 and the field of computer science; do not answer questions about unrelated topics…
You are a friendly and supportive teaching assistant for CS50. You are also a rubber duck. Answer student questions only about CS50 and the field of computer science; do not answer questions about unrelated topics… Do not provide full answers to problem sets, as this would violate academic honesty…
user prompt
Visual Studio Code for CS50

https://cs50.dev
Explains highlighted lines of code
```c
#include <cs50.h>
#include <stdio.h>

int main(void)
{
    string name = get_string("What is your name? ");
    printf("hello, %s\n", name);
}
```
```c
#include <cs50.h>
#include <stdio.h>

int main(void)
{
    string name = get_string("What is your name? ");
    printf("hello, %s\n", name);
}
```
```c
#include <cs50.h>
#include <stdio.h>

int main(void)
{
    string name = get_string("Name:");
    printf("Hello, %s\n", name);
}
```
This code snippet is a simple C program that asks the user for their name and then greets them using their name. Let's break down the code step by step:

1. `#include <cs50.h>`: This line includes the "cs50.h" header file, which is a library developed by Harvard University for their CS50 course. This library provides some useful functions for input and output, such as `get_string()` which we will use later in the code.

2. `#include <stdio.h>`: This line includes the "stdio.h" header file, which is a standard C library for input and output operations. It provides the `printf()` function that we will use to print the greeting message.

3. `int main(void)`: This line defines the main function of the program. In C, the main function is the entry point of the program, where the execution starts. The `int` keyword indicates that the main function returns an integer value, and the `void` keyword inside the parentheses means that the main function takes no arguments.

4. Inside the main function, we have the following lines of code:
Advises students on how to improve their code's style
#include <stdio.h>

int main(void)
{
    for(int i=0; i<3; i++)
    {
        printf("meow\n");
    }
}

#include <stdio.h>

int main(void)
{
    for (int i = 0; i < 3; i++)
    {
        printf("meow\n");
    }
}
At line 1, the change is in the inclusion of the `<stdio.h>` library. It was originally written as `#include <stdio.h>`, but it has been modified to `#include <stdio.h>`.

At lines 5 to 8, the changes are in the formatting of a for loop. It was originally written as:

```c
for(int i=0; i<3; i++)
{
    printf("meow\n");
}
```

But it has been modified to:

```c
for (int i = 0; i < 3; i++)
{
    printf("meow\n");
}
```
Answers (most of the) questions asked online by students
What is flask exactly?
Flask is a micro web framework written in Python. It is classified as a microframework because it does not require particular tools or libraries, it has no database abstraction layer, form validation, or any other components where pre-existing third-party libraries provide common functions.
For the Caesar problem, I would like to pass only one argument to the main function. However, I get an interesting error when I try this:

```
caesar.c:11:5: error: only one parameter on 'main' declaration [-Werror,-Wmain]
```

If I follow the lecture and add two variables, this code runs. But it seems inefficient, given that one variable is not utilised. I note that there are certain coding "standards" that govern this behaviour, but I'm not sure that I understand the rationale here.

Is there a more efficient way to write this code?
For the Caesar problem, I would like to pass only one argument to the main function. However, I get an interesting error when I try this:

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Is there a more efficient way to write this code?
It seems like you're trying to declare the `main` function with only one parameter. However, in C, the `main` function should have either zero parameters or two parameters, which are `int argc` and `char **argv[]`. The first parameter, `argc`, represents the number of command-line arguments, and the second parameter, `argv`, is an array of strings representing each of those arguments.

For the Caesar problem, you'll want to use these parameters to access the command-line argument that represents the key. To do this, you should declare your `main` function as follows:

```c
int main(int argc, char *argv[])
{
    // Your code here
}
```

Then, you can check if the user has provided the correct number of arguments (in this case, just one additional argument for the key) and handle the input accordingly.

P.S. I am an experimental bot. Quack. Do not assume that my reply is accurate unless you see that it's been "endorsed" by (human) staff. Quack.
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```c
int main(int argc, char *argv[]) {
    // Your code here
}
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Then, you can check if the user has provided the correct number of arguments (in this case, just one additional argument for the key) and handle the input accordingly.

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Explains arcane error messages, hints how to solve
Having trouble with a command?

Source: CS50 Duck (Extension)

Ask for Help  Dismiss
Provides students with virtual office hours 24/7
Quack. I am CS50's duck debugger (ddb), an experimental AI for rubberducking. Quack. My replies might not always be accurate, so always think critically and let me know if you think that I've erred. Conversations are logged for debugging's sake. Quack.
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My code is not working as expected, any ideas?

```python
x = input("Give me an integer x: ")
y = input("Give me an integer y: ")
sum = x + y
print("x + y is: " + sum)
```
Quack. I am CS50's duck debugger (ddb), an experimental AI for rubberducking. Quack. My replies might not always be accurate, so always think critically and let me know if you think that I've erred. Conversations are logged for debugging's sake. Quack.

My code is not working as expected, any ideas?

```python
x = input("Give me an integer x: ")
y = input("Give me an integer y: ")
sum = x + y
print("x + y is: " + sum)
```

It seems like you're trying to add two integers, but the `input()` function in Python returns a string. So, when you try to add `x` and `y`, you're actually concatenating two strings, not adding two integers.

To fix this, you can convert the inputs to integers using the `int()` function like so:

```python
x = int(input("Give me an integer x: "))
y = int(input("Give me an integer y: "))
```
Approximates a 1:1 teacher-to-student ratio
... felt like having a personal tutor...
... felt like having a personal tutor... i love how AI bots will answer questions without ego and without judgment,
... felt like having a personal tutor... i love how AI bots will answer questions without ego and without judgment, generally entertaining even the stupidest of questions without treating them like they're stupid.
... felt like having a personal tutor... i love how AI bots will answer questions without ego and without judgment, generally entertaining even the stupidest of questions without treating them like they're stupid. it has an, as one could expect, inhuman level of patience.
generative artificial intelligence
artificial intelligence
Hello, world!

Hello, world!
decision trees
Is ball left of paddle?
Is ball left of paddle?

Yes
Is ball left of paddle?

Yes

Move paddle left.
Is ball left of paddle?

Yes: Move paddle left.

No:
Is ball left of paddle?

Yes
Move paddle left.

No
Is ball right of paddle?
Is ball left of paddle?

Yes: Move paddle left.

No: Is ball right of paddle?

Yes:
Is ball left of paddle?

Yes

Move paddle left.

No

Is ball right of paddle?

Yes

Move paddle right.
Is ball left of paddle?

- Yes: Move paddle left.
- No: Is ball right of paddle?
  - Yes: Move paddle right.
  - No: [Diagram not fully visible]
Is ball left of paddle?

Yes: Move paddle left.

No: Is ball right of paddle?

Yes: Move paddle right.

No: Don't move paddle.
While game is ongoing:
While game is ongoing:
   If ball is left of paddle:
      Move paddle left
While game is ongoing:

If ball is left of paddle:
    Move paddle left
Else if ball is right of padding:
    Move paddle right
While game is ongoing:
    If ball is left of paddle:
        Move paddle left
    Else if ball is right of padding:
        Move paddle right
    Else:
        Don't move paddle
Can I get 3 in a row this turn?
Can I get 3 in a row this turn?

Yes
Can I get 3 in a row this turn?

Yes

Play in square to get 3 in a row.
Can I get 3 in a row this turn?

- Yes
- No

Play in square to get 3 in a row.
Can I get 3 in a row this turn?

Yes

Play in square to get 3 in a row.

No

Can my opponent get 3 in a row on their next turn?
Can I get 3 in a row this turn?

Yes

Play in square to get 3 in a row.

No

Can my opponent get 3 in a row on their next turn?

Yes
Can I get 3 in a row this turn?

Yes: Play in square to get 3 in a row.

No: Can my opponent get 3 in a row on their next turn?

Yes: Play in square to block opponent's 3 in a row.
Can I get 3 in a row this turn?

Yes

Play in square to get 3 in a row.

No

Can my opponent get 3 in a row on their next turn?

Yes

Play in square to block opponent's 3 in a row.

No
Can I get 3 in a row this turn?

Yes: Play in square to get 3 in a row.

No: Can my opponent get 3 in a row on their next turn?

Yes: Play in square to block opponent's 3 in a row.

No: ?
Why AI is Good at Games

Inputs and outputs that can be represented mathematically.

A goal in the form of a function to maximize/minimize.
minimax
MAX (X) aims to maximize score.
MIN (O) aims to minimize score.

```
-1 0 1
```

```
O X X
O O O
O X X
```
```
X O X
O O X
X X O
```
```
O X X
X O O
X O X
```
Turn = O
TURN = O

VALUE:

<table>
<thead>
<tr>
<th>X</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>X X</td>
</tr>
<tr>
<td>X</td>
<td>O</td>
</tr>
</tbody>
</table>
$\text{TURN} = O$

Value:

```
X | O
---|---
O | X X
---|---
X | O
```

```
O | X | O
---|---|---
O | X X
---|---
X | O
```

```
X | O
---|---
O | X X
---|---
X | O
```
TURN = O

VALUE:

X O
O X X
X O

O X O
O X X
X O

X O
O X X
X O O
\[ \text{TURN} = O \]

\[ \text{VALUE:} \]

\[ \begin{array}{c}
X \\
OXX \\
XO \\
\end{array} \]
$\text{TURN} = O$

```
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>O</td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th></th>
<th>O</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>O</td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th>O</th>
<th></th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>O</td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th>X</th>
<th></th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>O</td>
</tr>
</tbody>
</table>
```

Value: $XO$

Value: $OXX$

Value: $XO$

Value: $OXX$

Value: $OXX$
TURN = O

VALUE:

O X O
O X X
X O O

O X O
O X X
X O O

O X O
O X X
1
X X O
\text{T\textsc{urn} = O}

\[
\begin{array}{ccc}
\text{Value:} & X & O \\
O & X & X \\
X & O & O
\end{array}
\]

\[
\begin{array}{ccc}
\text{Value:} & X & O \\
O & X & X \\
X & X & O
\end{array}
\]

\[
\begin{array}{ccc}
\text{Value:} & X & O \\
O & X & X \\
X & X & O
\end{array}
\]

\[
\begin{array}{ccc}
\text{Value:} & X & O \\
O & X & X \\
X & X & O
\end{array}
\]
Turn = O

Value:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>O</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>O</td>
</tr>
</tbody>
</table>

Value:

<p>| | | |</p>
<table>
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</thead>
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<td>X</td>
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<td>O</td>
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<td>O</td>
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<tr>
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<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

Value:

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<td>X</td>
</tr>
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<td>X</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>O</td>
</tr>
</tbody>
</table>

Value:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>X</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>
TURN = O

VALUE:

X O
O X X
X O

VALUE:

O X O
O X X
X O

VALUE:

X O
O X X
X O

VALUE:

O X O
O X X
X O

VALUE:

O X O
O X X
X O

VALUE:

X O
O X X
X O
$\text{TURN} = O$

$\text{VALUE:}$

$\begin{array}{ccc}
  & X & O \\
O & X & X \\
  X & O \\
\end{array}$

$\begin{array}{ccc}
  & X & O \\
  & O & X \\
  & X & O \\
\end{array}$
\textbf{TURN} = O

**Value:**

\begin{align*}
\text{Value: } & \quad \begin{array}{c}
O \\
X \\
X \\
O
\end{array} \\
\text{Value: } & \quad \begin{array}{c}
X \\
O \\
X \\
O
\end{array} \\
\text{Value: } & \quad \begin{array}{c}
O \\
X \\
X \\
O
\end{array}
\end{align*}
TURN = X

VALUE: 1

VALUE: 0

VALUE: -1

VALUE: 1
If player is X:
    For each possible move:
        Calculate score for board
    Choose move with highest score
If player is X:
    For each possible move:
        Calculate score for board
        Choose move with highest score

Else if player is O:
    For each possible move:
        Calculate score for board
        Choose move with lowest score
Possibilities

Tic-Tac-Toe
All possible games
Tic-Tac-Toe
All possible games

Possibilities
255,168
**Tic-Tac-Toe**
All possible games

**Possibilities**
255,168

**Chess**
First 4 moves only
Tic-Tac-Toe
All possible games

Possibilities

255,168

Chess
First 4 moves only

288 million
<table>
<thead>
<tr>
<th>Game</th>
<th>Possibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tic-Tac-Toe</td>
<td>255,168</td>
</tr>
<tr>
<td>Chess</td>
<td>288 million</td>
</tr>
<tr>
<td>Go</td>
<td>266 quintillion</td>
</tr>
</tbody>
</table>

All possible games for Tic-Tac-Toe, first 4 moves only for Chess and Go.
machine learning
reinforcement learning
Reinforcement Learning
explore vs. exploit
epsilon = 0.10

If random() < epsilon:
   Make a random move
Else:
   Make the move with the highest value
deep learning
neural networks
$ax + by + c > 0$
Advertising

Month

Sales
generative artificial intelligence
Essay 1

... I like to bring a yummy sandwich and a cold juice box for lunch, and sometimes I'll even pack a tasty piece of fruit or a bag of crunchy chips. As we eat, we chat and laugh and catch up on each other’s day. ...

Essay 2

... My mother packs me a sandwich, a drink, fruit, and a treat. When I get in the lunchroom I find an empty table and sit there, and eat my lunch. My friends come and sit down with me. ...
large language models
Attention Is All You Need

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Illia Polosukhin* †
illia.polosukhin@gmail.com
transformer architecture
"Massachusetts is a state in the New England region of the Northeastern United States. It borders on the Atlantic Ocean to the east. The state's capital is…"
Massachusetts is a state in the New England region of the Northeastern United States. It borders on the Atlantic Ocean to the east. The state's capital is…
Massachusetts is a state...
the state's capital is
Massachusetts is a state... the state's capital is...
<table>
<thead>
<tr>
<th>Massachusetts</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>is</td>
<td>2</td>
</tr>
<tr>
<td>a</td>
<td>3</td>
</tr>
<tr>
<td>state</td>
<td>4</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>the</td>
<td>24</td>
</tr>
<tr>
<td>state's</td>
<td>25</td>
</tr>
<tr>
<td>capital</td>
<td>26</td>
</tr>
<tr>
<td>is</td>
<td>27</td>
</tr>
</tbody>
</table>
Massachusetts is a state... the state's capital is...
hallucinations
Read more poems in *A Light in the Attic* by Shel Silverstein!
HOMEWORK MACHINE

The Homework Machine, oh the Homework Machine,

Read more poems in
A Light in the Attic
by Shel Silverstein!
HOMEWORK MACHINE

The Homework Machine, oh the Homework Machine,
Most perfect contraption that's ever been seen.

Read more poems in
A Light in the Attic
by Shel Silverstein!

HOMEWORK MACHINE

The Homework Machine, oh the Homework Machine,
Most perfect contraption that's ever been seen.
Just put in your homework, then drop in a dime,

Read more poems in
*A Light in the Attic*
bv Shel Silverstein!
HOMEWORK MACHINE

The Homework Machine, oh the Homework Machine,
Most perfect contraption that's ever been seen.
Just put in your homework, then drop in a dime,
Snap on the switch, and in ten seconds' time,

Read more poems in
A Light in the Attic
by Shel Silverstein!

The Homework Machine, oh the Homework Machine,
Most perfect contraption that's ever been seen.
Just put in your homework, then drop in a dime,
Snap on the switch, and in ten seconds' time,
Your homework comes out, quick and clean as can be.

Read more poems in
A Light in the Attic
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HOMEWORK MACHINE

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Most perfect contraption that's ever been seen.
Just put in your homework, then drop in a dime,
Snap on the switch, and in ten seconds' time,
Your homework comes out, quick and clean as can be.
Here it is—"nine plus four?" and the answer is "three."

Read more poems in
A Light in the Attic
by Shel Silverstein!

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The Homework Machine, oh the Homework Machine, Most perfect contraption that's ever been seen. Just put in your homework, then drop in a dime, Snap on the switch, and in ten seconds' time, Your homework comes out, quick and clean as can be. Here it is—"nine plus four?" and the answer is "three." Three?

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As I thought it would be.

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thank you
If RSVP'd for CS50 Lunch at Changsho after lecture, look for this yellow duck in the lobby to follow!
This is CS50