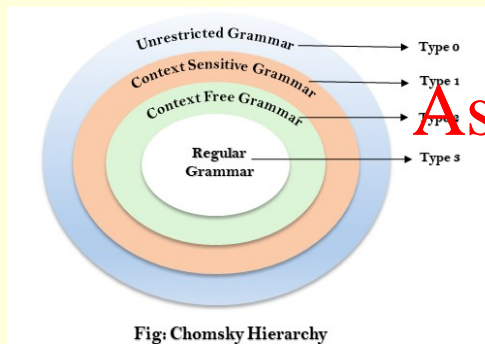


# COSC1107 Computing Theory

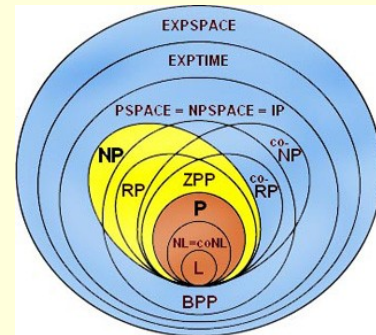
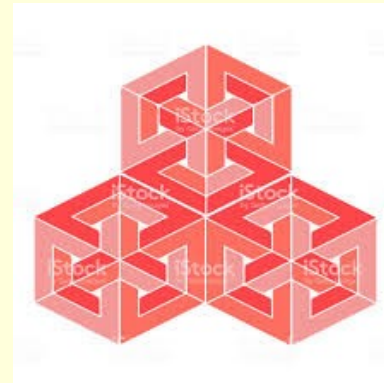
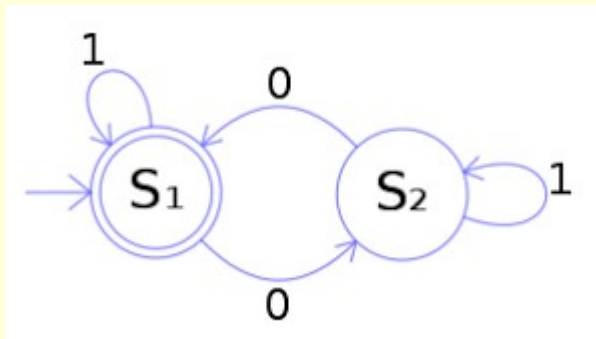
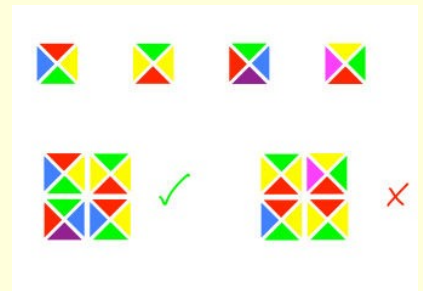
(We will commence soon. We are just allowing a few minutes for people to join and set up. *Please mute your microphone unless you are speaking.* You can raise your hand or use the chat at any time.)

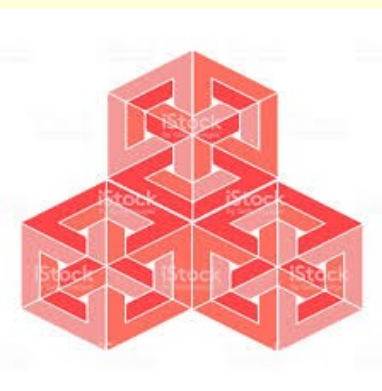
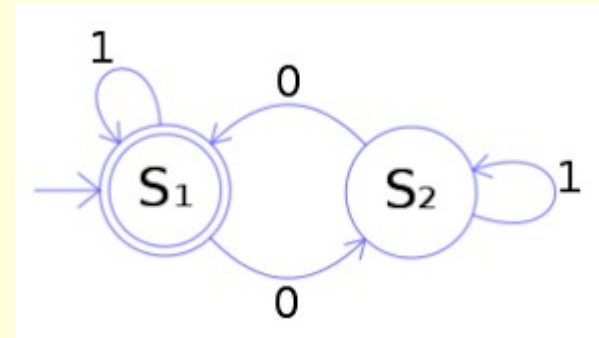
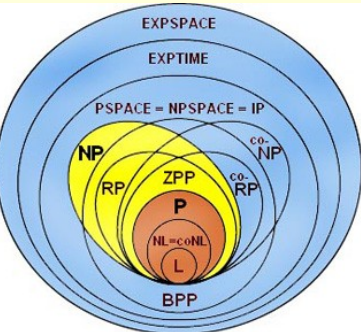


Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder





# COSC1107

## Assignment Project Exam Help

# Computing Theory

<https://powecoder.com>

Pushdown Automata

Add WeChat powecoder

## Week 3

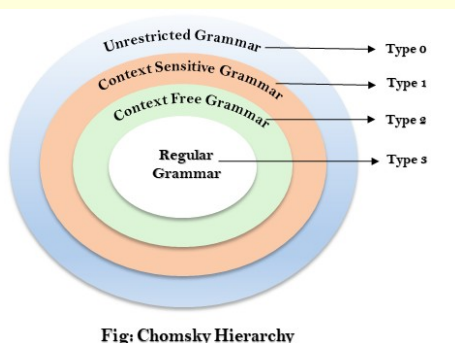
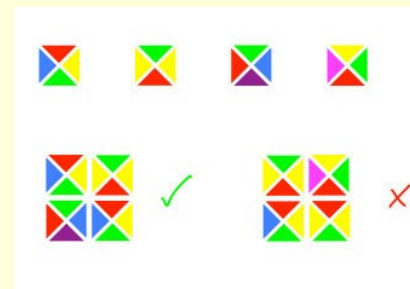


Fig: Chomsky Hierarchy

**James Harland**

[james.harland@rmit.edu.au](mailto:james.harland@rmit.edu.au)

\* With thanks to Sebastian Sardina

*Intro music 'Far Over' playing now ...*



Week 3

Computing Theory

# Acknowledgement



RMIT University acknowledges the people of the Woiwurrung and Boon wurrung language groups of the eastern Kulin Nations on whose unceded lands we conduct the business of the University. RMIT University respectfully acknowledges their Ancestors and Elders, past and present.

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

RMIT also acknowledges the Traditional Custodians and their Ancestors of the lands and waters across Australia where we conduct our business.

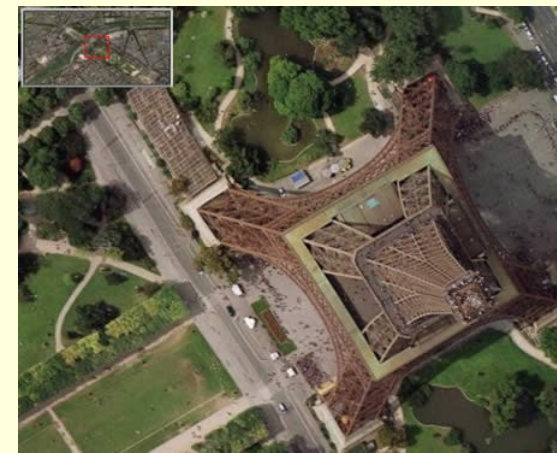
# Overview

- Questions?
- Platypus Game
- Questions?
- Nondeterminism
- Questions?
- Pushdown Automata
- Questions?

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder





# Questions?



Questions?



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Questions?



# The Platypus Game

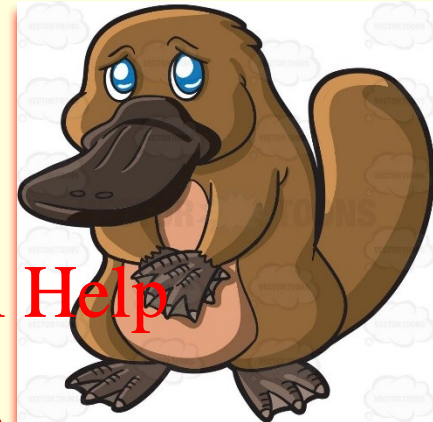


Assignment Project Exam Help

<https://powcoder.com>



Add WeChat powcoder



# The Platypus Game



Get your 268-match tournament done soon!  
Provides data on how many matches we can play

What should we do in Assignment 2? Help

Issues: <https://powcoder.com>

1. How do we best approximate a full tournament?  
(ie 268,435,456 machines)
2. What is the best scoring system?
3. Rule changes?
4. Other ideas?



# The Platypus Game



How do we best approximate a full tournament?  
(ie 268,435,456 machines)

"Round robin + knockout"

- Play a full tournament with say 1,000 machines (~500,000 matches)
- Need around 268,000 such tournaments
- Knockout round with ~268,000 machines (~500,000 matches)
- Around 134,000,500,000 matches
- Assignment 1 results will indicate how feasible this is
- Can play less than 1,000 if this is too many

"Champions League"

- Play as many (random) matches as possible
- Rank all machines via a ladder
- Top of the ladder at the end of the matches is the champion





# The Platypus Game



## What is the best scoring system?

- More points for changing green to yellow than vice-versa
- Bonus or penalty scores for forfeiting the game
- Bonus or penalty scores for reaching a tree
- Score multiplied by the number of platypuses in the machine
- Games run on more than one starting set of cells (all green, "chess like", random)
- Shortening or lengthening the maximum number of turns before a game ends (currently 100)
- Tiebreaker?
- Other ideas?

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



# The Platypus Game



## Rule changes?

- More players: 3? 4? 8? 10? ...
- Constrain machines (eg must contain at least two platypodes in row 4)
- Larger or small number of cells? (11? 31? 101?)
- Different rules for teaching a tree?
  - Bounce
  - Back to Billabong
- *More colours?*
- *More animals?*
- *2-dimensional board?*
- *Machine changes during play?*
- *NPCs?*

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

## Other ideas?

Survey will be used to determine assignment specification

# Questions?



Questions?



Assignment Project Exam Help

<https://powcoder.com>

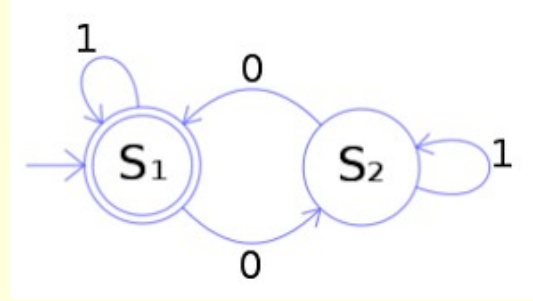


Add WeChat powcoder

Questions?



# Review



Questions?

Last week:

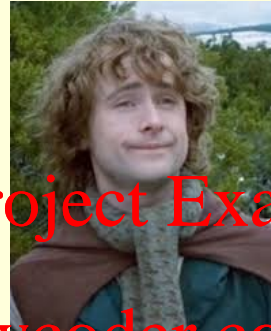
- Finite State Automata
- Nondeterminism

Assignment Project Exam Help

<https://powcoder.com>

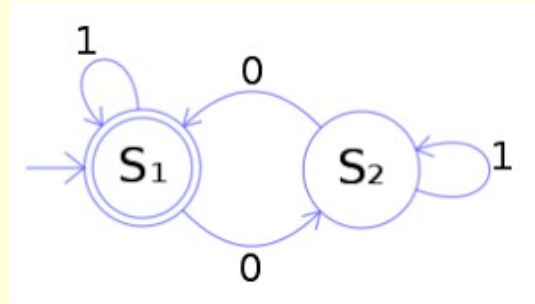
- What is the language of  $M$ ?
- Give a DFA/NFA for language  $L$  ...

Add WeChat powcoder





# Non-determinism

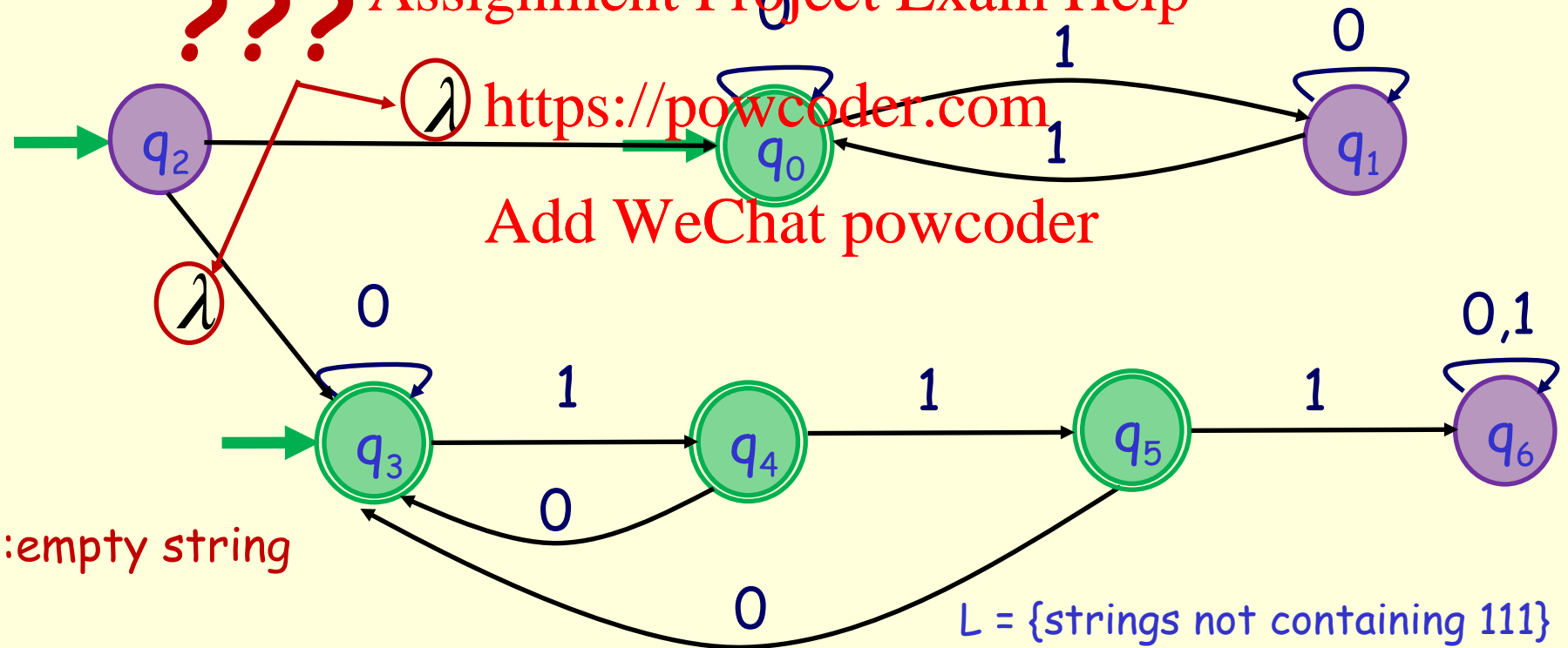


- Specifying all combinations can be awkward
- Often tempting to omit 'error' states
- Elegant and simpler to include **multiple executions (!!)**
- Makes combining machines a lot simpler

???

Assignment Project Exam Help

$L = \{\text{strings with even \# 1's}\}$



<https://powcoder.com>

Add WeChat powcoder

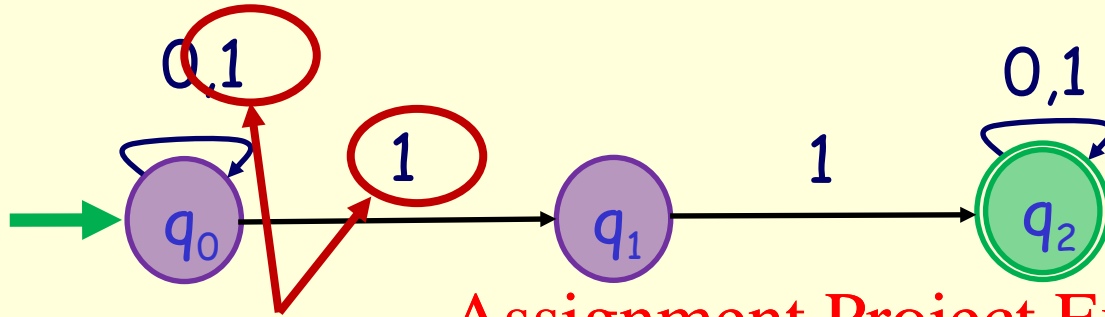
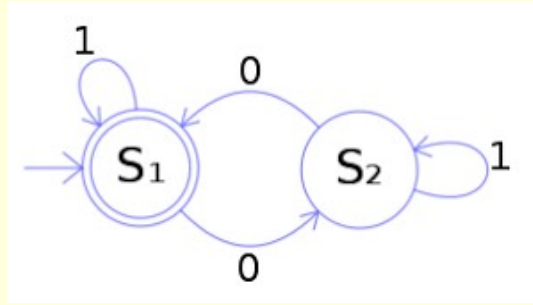
:empty string

$L = \{\text{strings not containing 111}\}$

Computing Theory

Week 3

# Non-determinism



Assignment Project Exam Help

Oil! You can't do that!

<https://powcoder.com>

Add WeChat powcoder

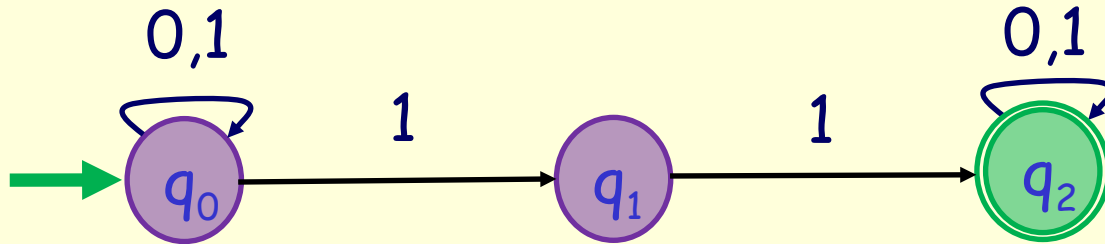
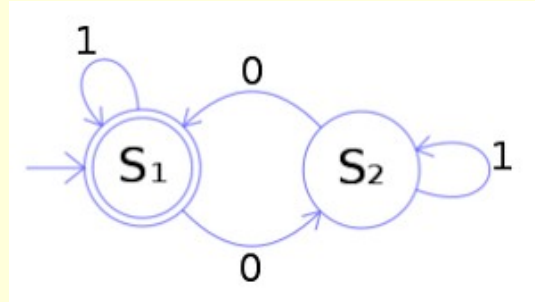


$$L(M) = (0 \mid 1)^* 11 (0 \mid 1)^* = \{\text{strings containing } 11\}$$

Yes, you can, Sam ...

$$L(M) = \{w \mid M \text{ accepts } w \text{ by some execution}\}$$

# Non-determinism



Assignment Project Exam Help

Executions for 011:

$q_0 q_0 q_0$  no  
 $q_0 q_0 q_1$  no  
 $q_0 q_1 q_2$  yes

So 011  $L(M)$

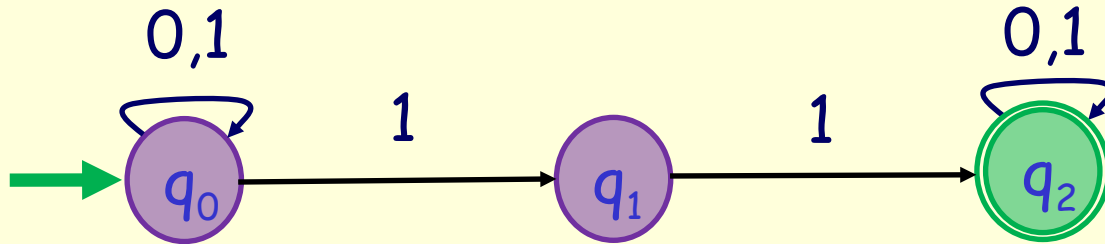
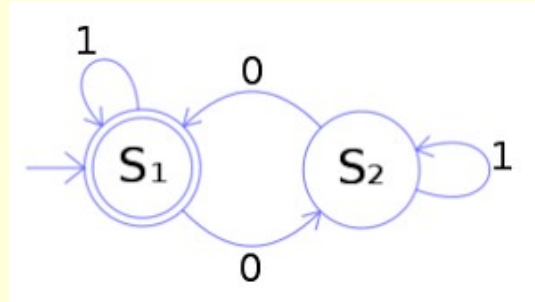
$L(M) = (0 \mid 1)^* 11 (0 \mid 1)^* = \{\text{strings containing 11}\}$   
 $L(M) = \{w \mid M \text{ accepts } w \text{ by some execution}\}$

Executions for 1101:

$q_0 q_0 q_0 q_1$  no  
 $q_0 q_0 q_0 q_1$  no  
 $q_0 q_1 q_1$  no  
 $q_1 q_2 q_2 q_2$  yes

So 1101  $L(M)$

# Non-determinism



Assignment Project Exam Help

Executions for 001:

$q_0 q_0 q_0$  no  
 $q_0 q_0 q_1$  no

So 001  $\notin L(M)$

Executions for 0101:

$q_0 q_0 q_0 q_1$  no  
 $q_0 q_0 q_0 q_1$  no  
 $q_0 q_1$  no

So 0101  $\notin L(M)$

**"There is path 'via' w from the start state to a final state"**  
 $L(M) = \{w \mid \text{there is path 'via' w from the start state to a final state}\}$   
 $L(M) = \{w \mid M \text{ accepts } w \text{ by some execution}\}$

[FSA5.jff](#)



# Questions?



## Questions?



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

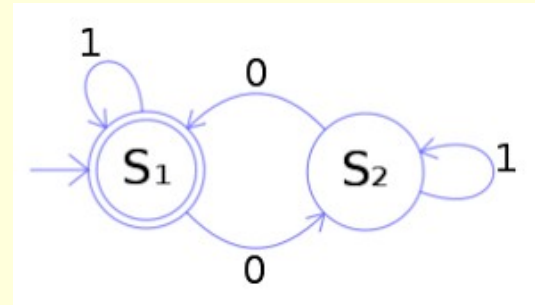
## Questions?



Week 3

Computing Theory

# Formal Definition



A finite state automaton  $M$  is a 5-tuple  $(Q, \Sigma, q_0, F)$

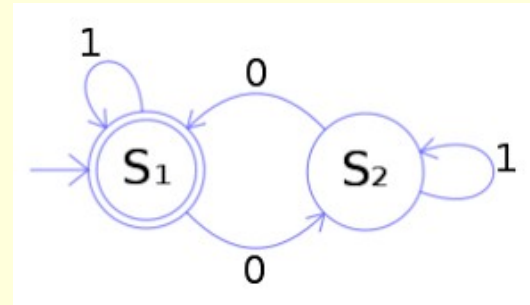
- $Q$  is a finite set of states
- $\Sigma$  is a finite alphabet
- $Q \times Q$  is the transition function
- $q_0$  is the start state of the machine
- $F \subseteq Q$  is the set of accepting or final states

Note:

- There is exactly one start state
- There can be many accepting states (can include the start state)

$$L(M) = \{w \mid M \text{ accepts } w \text{ (on some execution)}\}$$

# Formal Definition



A **nondeterministic** finite state automaton  $M$  is a 5-tuple  $(Q, \Sigma, q_0, F)$

- $Q$  is a finite set of **states**
- $\Sigma$  is a finite **alphabet**
- $Q \times \Sigma \rightarrow 2^Q$  is the **nondeterministic transition function**
- $q_0$  is the **start state** of the machine
- $F \subseteq Q$  is the set of **accepting or final states**

Note:

- There is exactly one **start state**
- There can be many **accepting states** (can include the start state)

$$L(M) = \{w \mid M \text{ accepts } w \text{ (on **some** execution)}\}$$

# Questions?



## Questions?



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

## Questions?

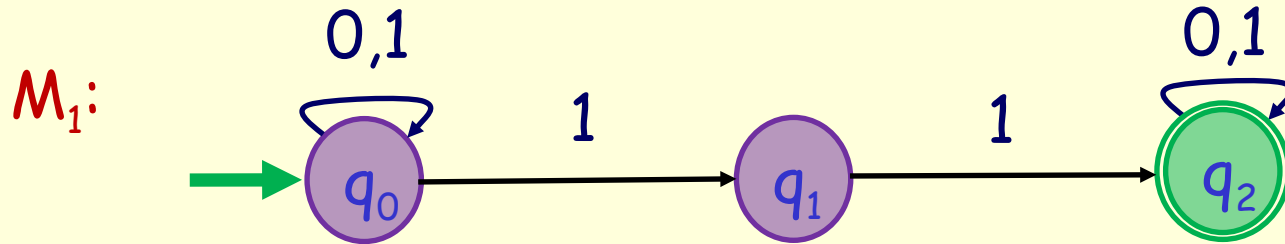
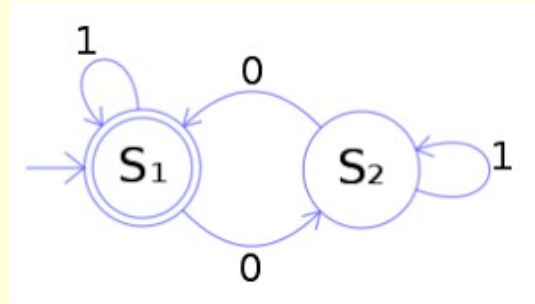


Week 2

Computing Theory



# Non-determinism

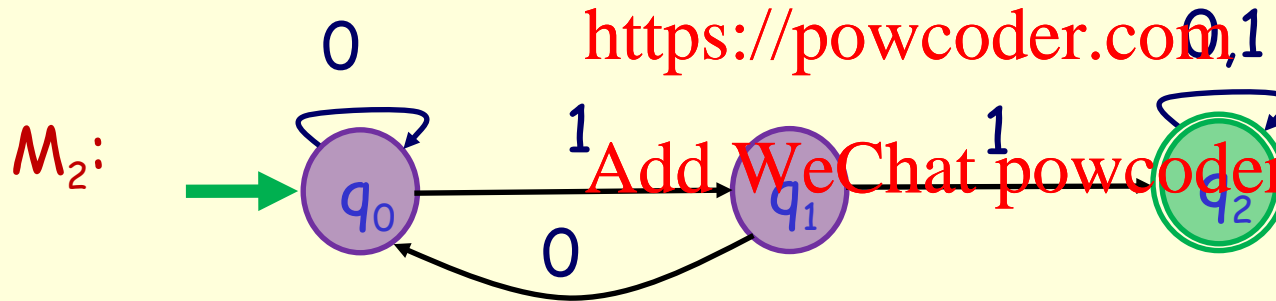


nondeterministic

$L(M_1) = \{\text{strings containing } 11\}$

Assignment Project Exam Help

<https://powcoder.com>

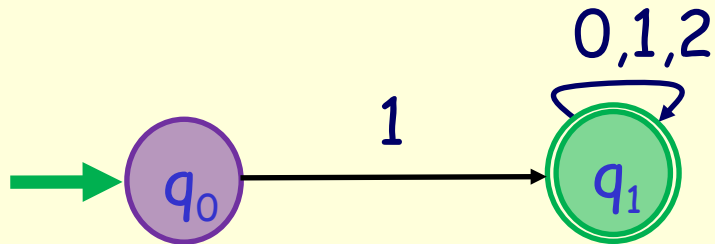
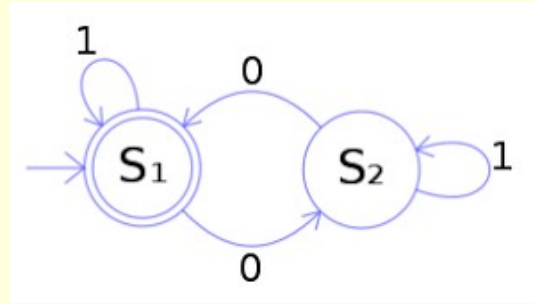


deterministic

$L(M_2) = \{\text{strings containing } 11\} = L(M_1)$  so  $M_1$  and  $M_2$  are **equivalent**

Is there always an equivalent deterministic machine? **YES!**

# Non-determinism

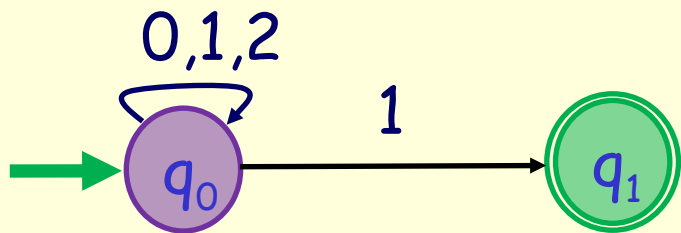


$$L(M) = \{ \text{strings over } \{0,1,2\} \\ \text{starting with 1} \} \\ = 1(0 \mid 1 \mid 2)^*$$

Assignment Project Exam Help  
deterministic

<https://powcoder.com>

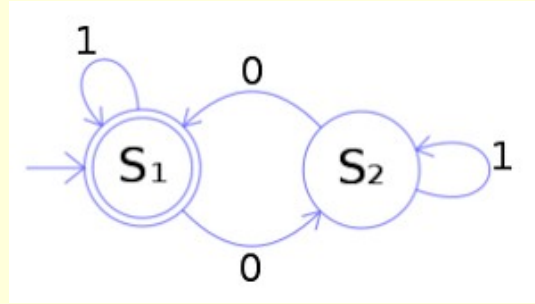
Add WeChat powcoder



$$L(M) = \{ \text{strings over } \{0,1,2\} \\ \text{ending with 1} \} \\ = (0 \mid 1 \mid 2)^* 1$$

nondeterministic

# Limits of FSAs

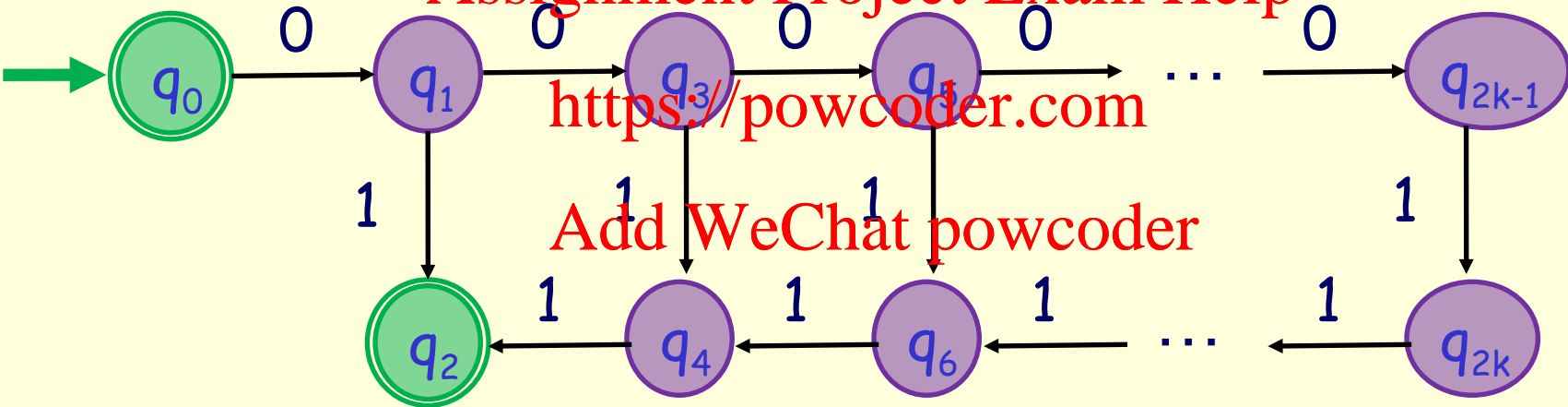


Give an FSA for the language  $L = \{0^n 1^n \mid n \geq 0\}$   
 $L = \{, 01, 0011, 000111, 00001111, 0000011111, \dots\}$

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



$L = \{0^n 1^n \mid n \leq k\} = \{, 01, 0011, 000111, \dots, 0^k 1^k\}$

# Questions?



Questions?



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Questions?

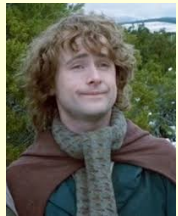
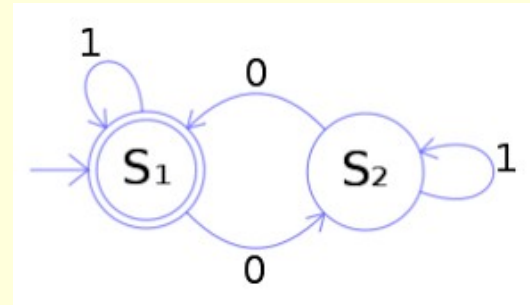




# Pushdown Automata



What do computers do again?



- Input and output
- Processing
- Memory

Assignment Project Exam Help



What is the **next** simplest computer?

<https://powcoder.com>

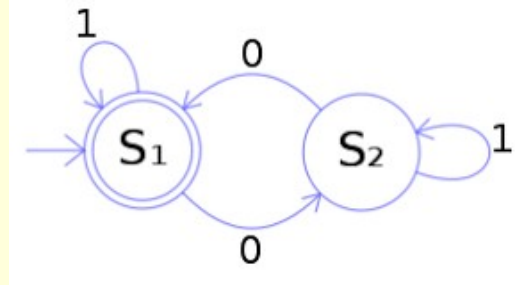
Add WeChat powcoder

- **Input:** a string
- **Output:** yes or no (decision problem)
- **Memory:** a fixed amount
- **Processing:** changes between a finite number of states



Memory has the biggest effect, so ...

# Brackets



Do the brackets balance?

( ( ( ) ( ( ( ) ) ) ( ) ) )

1 2 3 2 3 4 5 4 3 2 1 0 YES

( ( ( ( ( ( ( ) ) ) ) ) ( ) ) )

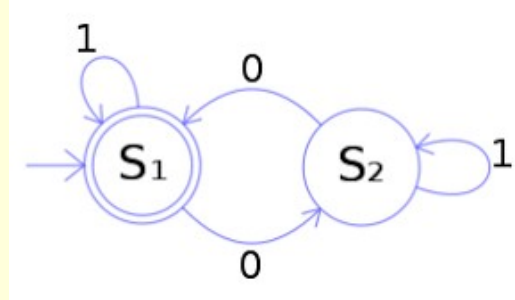
1 2 3 4 5 6 5 4 3 2 3 2 1 0 YES

( ( ( ) ( ( ( ) ) ) ) ) (

1 2 3 2 3 4 5 4 3 2 1 0 -1 0 (!!) NO

$L = \{ \text{strings over } \{ ( , ) \} \text{ with balanced brackets} \}$

# Brackets



$L = \{ \text{strings over } \{ (, ) \} \text{ with balanced brackets} \}$

Algorithm to recognise  $L$ :

- Count the brackets from left to right
- +1 for each (
- 1 for each )
- If the count reaches -1, reject ("too many )'s")
- Accept if the count is 0 at the end of the string (else "too many ('s")

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



What if there are multiple kinds of brackets ( [ { ??

$((\{ \} [ ]))$     yes  
 $((\{ [ \} ]))$     no

(think HTML ...)

Here we need to store the **sequence**, not just the count

# Pushdown Automata



PSA = FSA + stack

## Stack

- linear sequence of items
- Last in first out (LIFO)
- Only two operations
- **Push:** put an item on the stack (at the top)
- **Pop:** take the top item off the (non-empty) stack
- Often used in implementations of recursive procedure calls



Assignment Project Exam Help

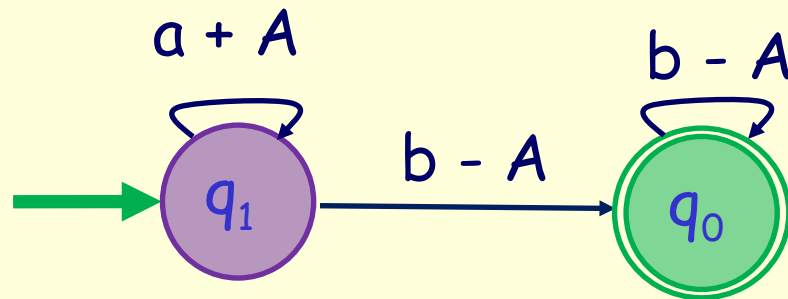
<https://powcoder.com>

Add WeChat powcoder

# Pushdown Automata

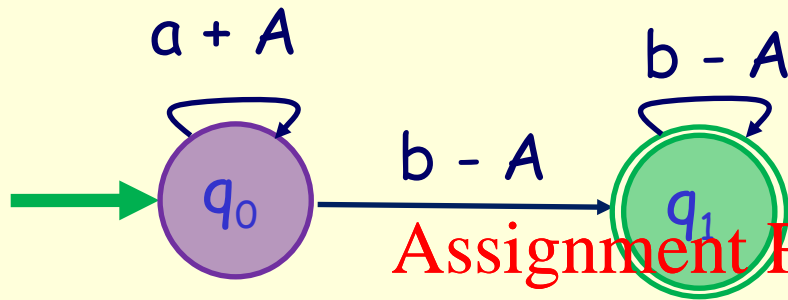


- Stack operations:
  - Push** a single item onto the top of the stack
  - Pop** the top item off the top of the stack
- Stack is **initially empty**
- String is **accepted** if execution finishes in an accepting state **AND** the stack is empty
- String is rejected if any of the following:
  - Execution finishes before input is finished
  - Empty stack is popped
  - Stack not empty at end
  - Execution finishes in a non-accepting state





# Pushdown Automata



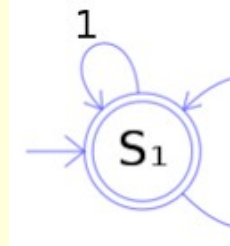
Assignment Project Exam Help

Input: aaabbb

<https://powcoder.com>

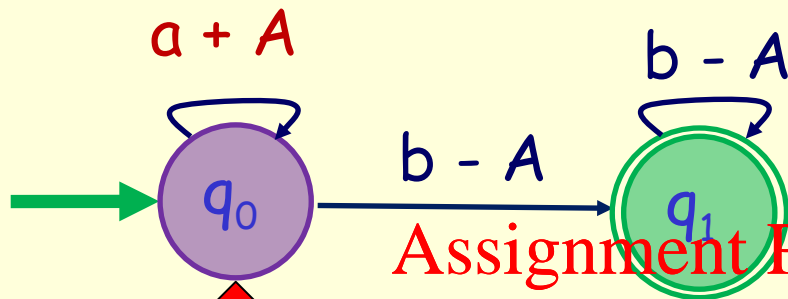
Stack

Add WeChat powcoder



shutterstock.com • 1170334213

# Pushdown Automata



Input: aaabbb

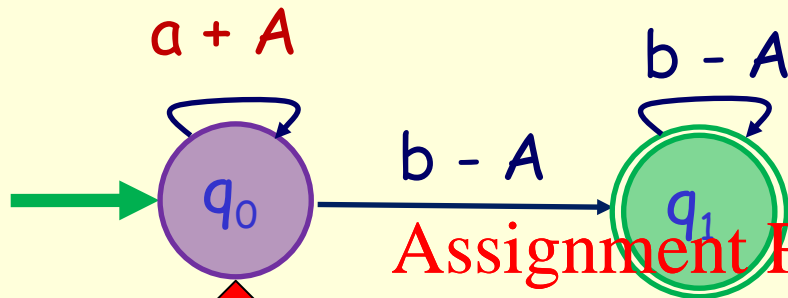
Assignment Project Exam Help

<https://powcoder.com>

Stack

Add WeChat powcoder

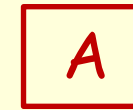
# Pushdown Automata



Input: aaabbb

Assignment Project Exam Help

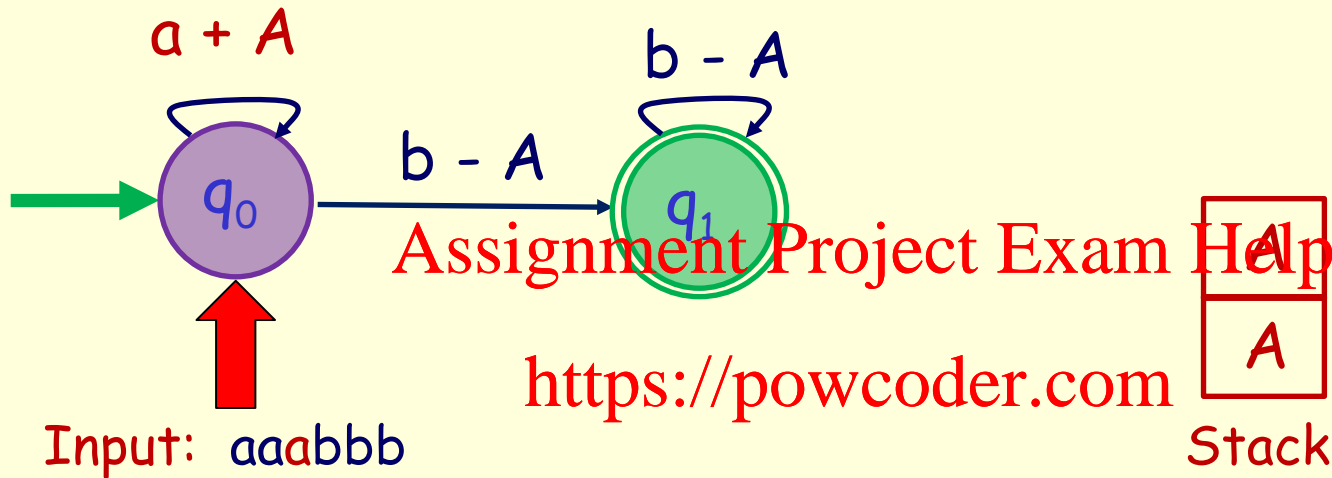
<https://powcoder.com>



Stack

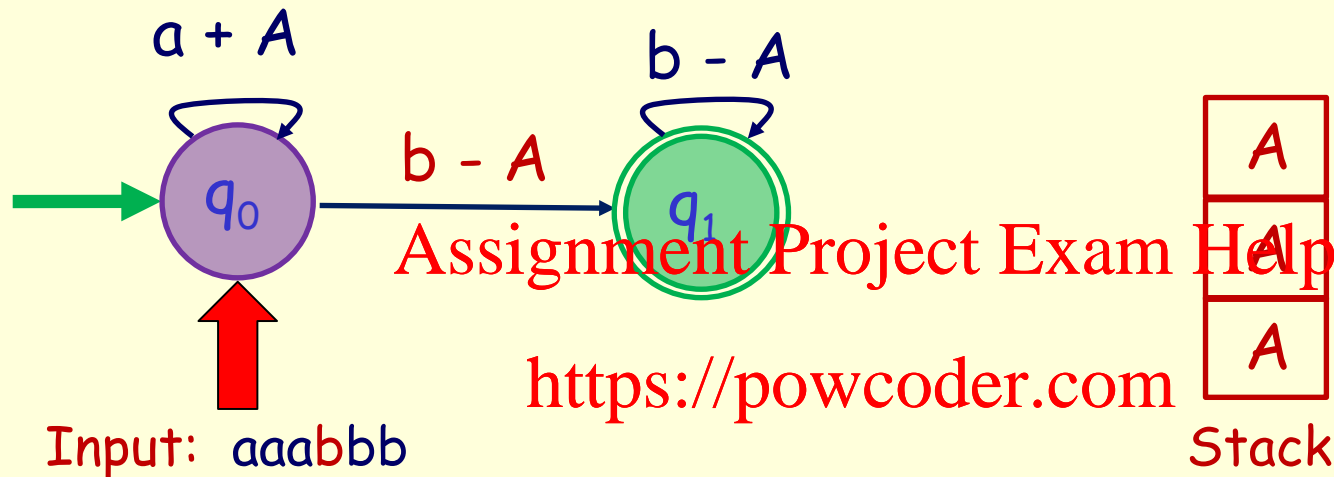
Add WeChat powcoder

# Pushdown Automata



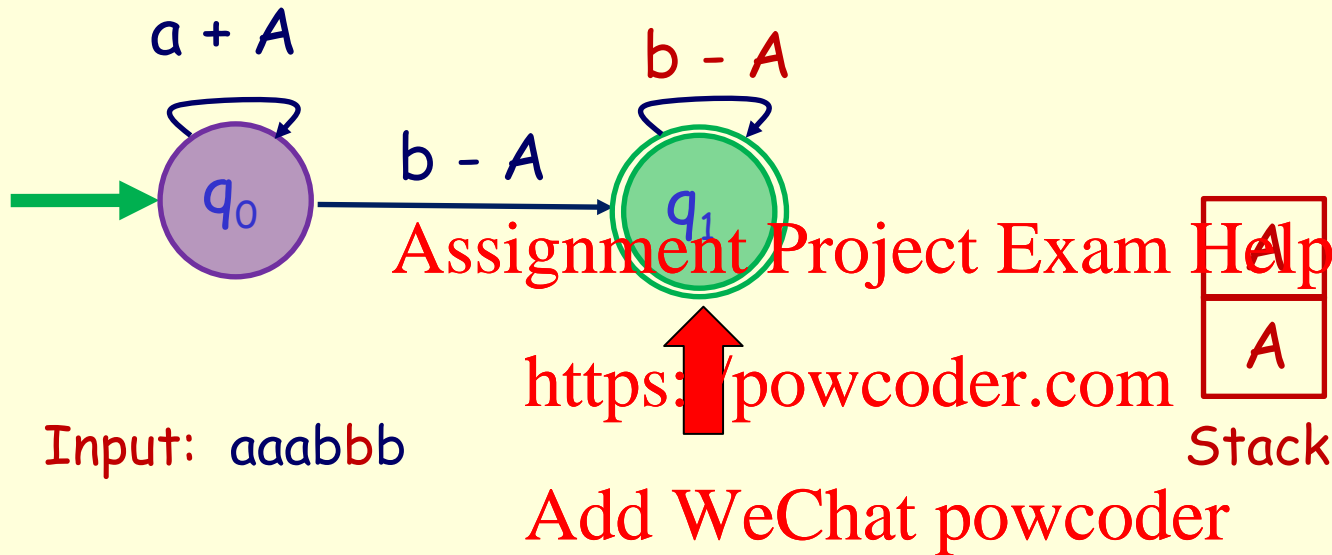
Add WeChat powcoder

# Pushdown Automata

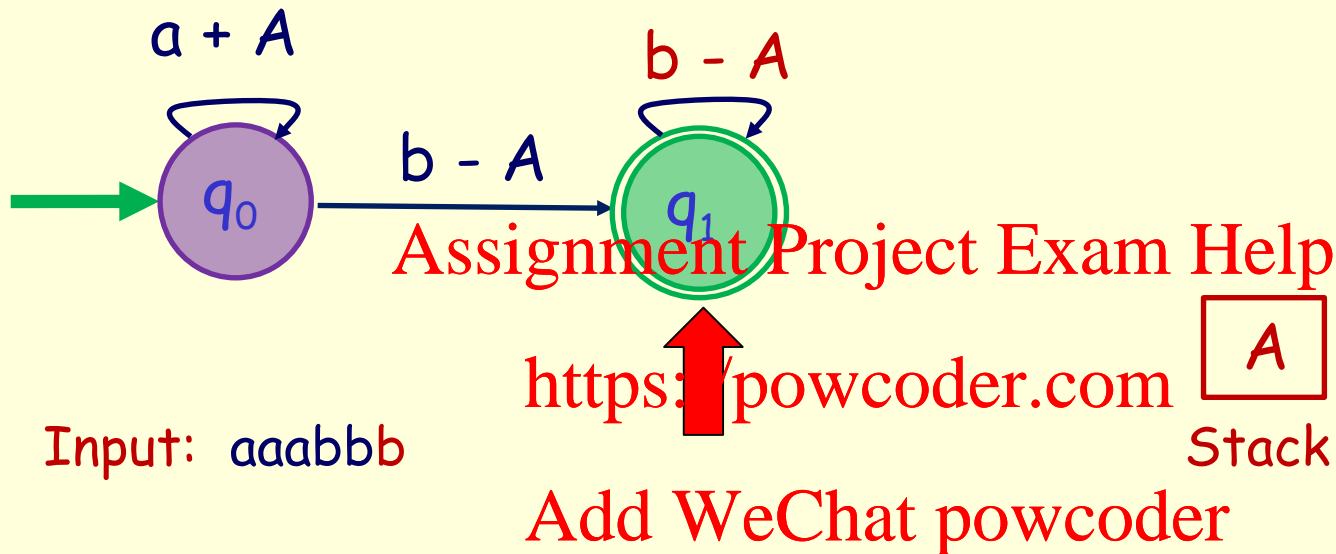




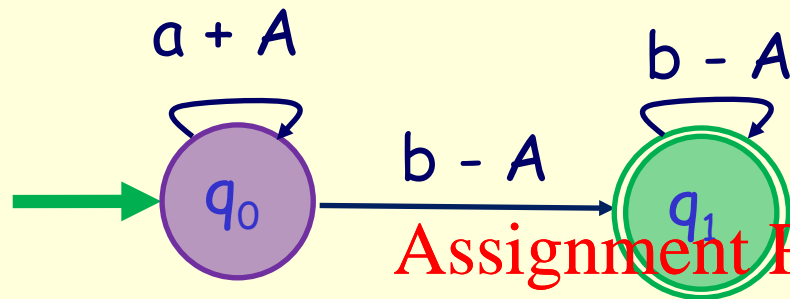
# Pushdown Automata



# Pushdown Automata



# Pushdown Automata



**ACCEPTED!**

Assignment Project Exam Help

<https://powcoder.com>

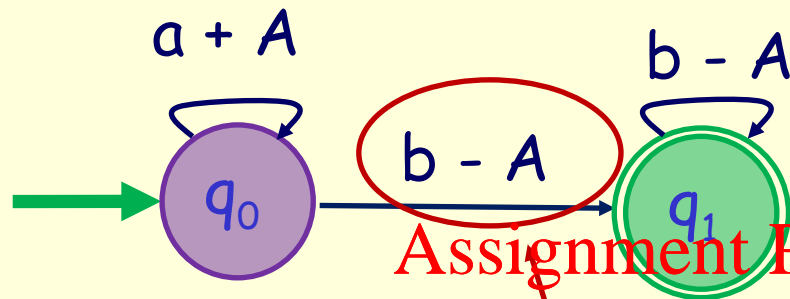
Input: aaabbb

Stack

Add WeChat powcoder  
PDA1.jff



# Pushdown Automata



**REJECTED!**

Input: aaabb

$L(M) = ??$

$L(M) = \{a^n b^n \mid n \geq 1\} ??$

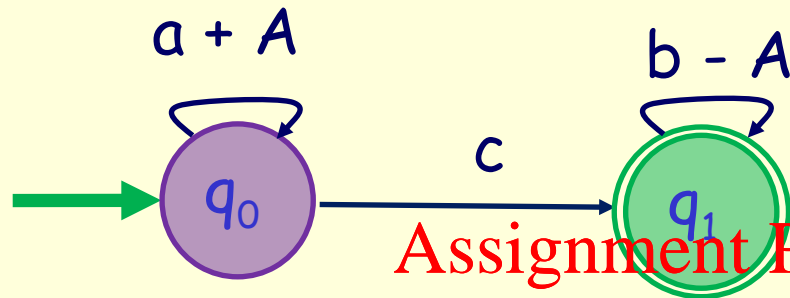
Assignment Project Exam Help  
<https://powcoder.com>  
 B popped from the Stack  
 Add WeChat powcoder

A



**Key Idea: How could the stack be emptied?**

# Pushdown Automata



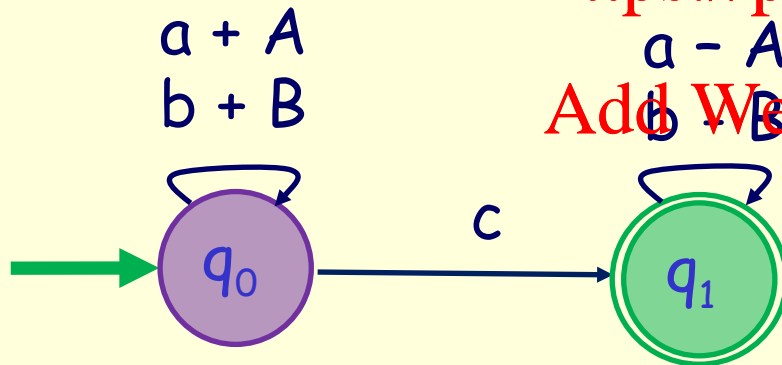
$L(M) = ??$

[PDA2.jff](#)

Assignment Project Exam Help  $L(M) = \{a^n b^n \mid n \geq 0\}$

<https://powcoder.com>

Add WeChat powcoder



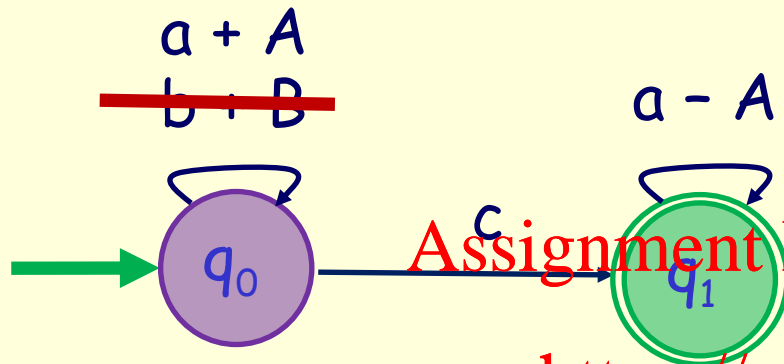
$L(M) = ??$

[PDA3.jff](#)

$L(M) = \{wcw^R \mid w \text{ is a string over } \{a,b\}\}$   
 ( $w^R$  is the reverse of the string  $w$ )



# Pushdown Automata



$L(M) = ??$

PDA4.jff

Assignment Project Exam Help

<https://powcoder.com>

Key Idea: How could the stack be emptied?

**In:**  $c, aca, aacaa, aaacaaa, \dots$

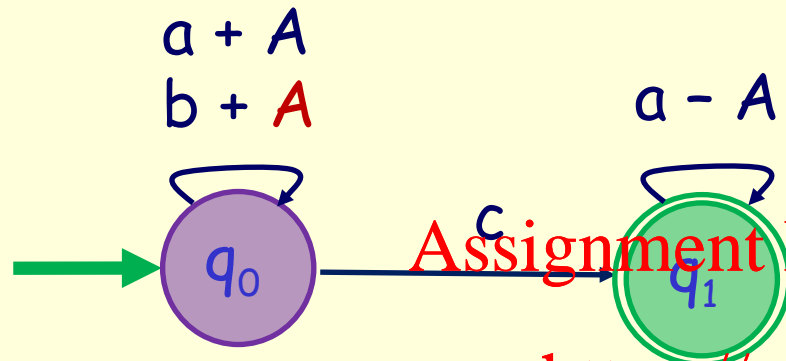
Add WeChat powcoder

**Out:**  $ac, bca, abcaa, bbacaaa, cb, \dots$

$$L(M) = \{a^n c a^n \mid n \geq 0\}$$



# Pushdown Automata



$L(M) = ??$

PDA5.jff

Assignment Project Exam Help

<https://powcoder.com>

Key Idea: How  
could the stack be  
emptied?

**In:**  $c, bca, aacaa, abbcaga, \dots$

Add WeChat powcoder

**Out:**  $ac, bbca, abcb, bbacaaaa, cb, \dots$

$$L(M) = \{ wca^n \mid w \{a,b\}^*, |w| = n \}$$



# Quiz time!

Go to **Canvas** and find the quiz **Lectorial 3 Quiz**

- Not worth any marks
- Middle "question" will require some thinking - you can consult other students if you wish
- Time limit will be <https://www.powcoder.com>

**Assignment Project Exam Help**



Week 3



Computing Theory

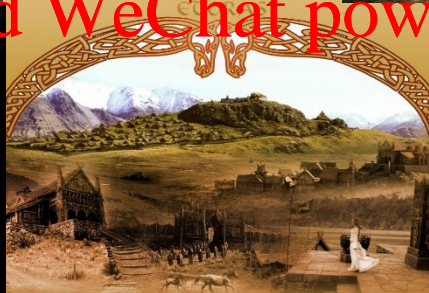




# Go!

The pictures will take 10 minutes to disappear!

*Thomas music means 1 minute left!*



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



# Questions?



Questions?



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Questions?







twinkl.com



# How did you go?

**Question 1:** Which of the following statements are correct?

- Pushdown automata are named after Penelope Pushdown. **FALSE**
- Pushdown automata add a queue to finite state automata. **FALSE**
- Pushdown automata add a list to finite state automata. **FALSE**
- Pushdown automata add a stack to finite state automata. **True**
- Pushdown automata add two stacks to finite state automata. **FALSE**
- A string is accepted by a pushdown automaton if execution finishes in an accepting state AND the stack is empty. **True**
- A string is accepted by a pushdown automaton if execution finishes in an accepting state OR the stack is empty. **FALSE**

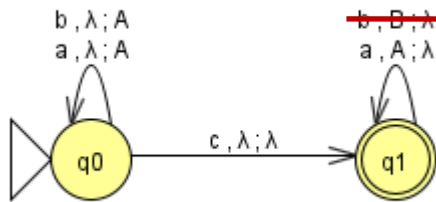
# How did you go?



twinkl.com

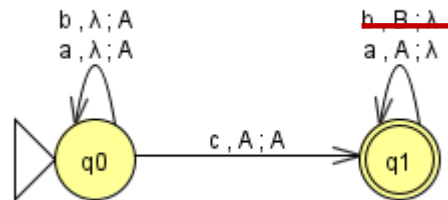


**Question 2:** What languages are accepted by the following machines?

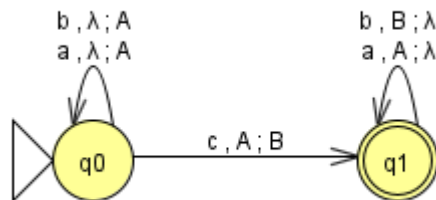


Assignment Project Exam Help  
 $L_1 = \{wca \mid w \in \{a,b\}^*, |w| = n\}$

<https://powcoder.com>



Add WeChat powcoder  
 $L_2 = \{wca \mid w \in \{a,b\}^*, |w| = n, n \geq 1\}$



$L_3 = \{wcba^{n-1} \mid w \in \{a,b\}^*, |w| = n, n \geq 1\}$

Computing Theory

# FSA vs PDA

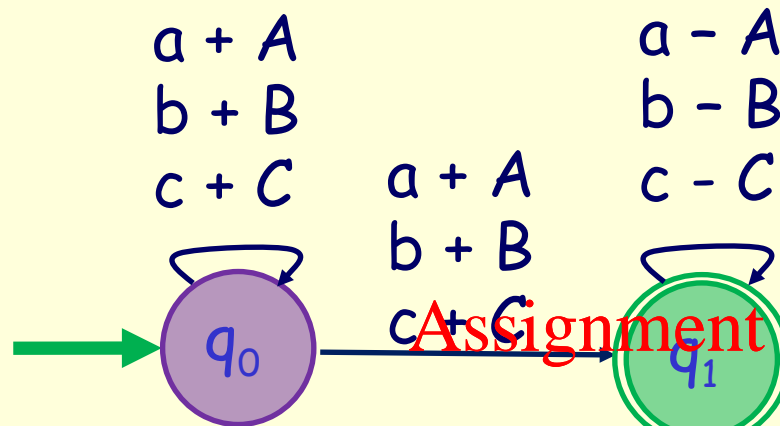


	FSA	PDA
Input	String	String
Output	Yes or no	Yes or no
Processing	One symbol at a time, left to right	One symbol at a time, left to right*
Memory	Current state	Current state + stack
Acceptance	Final state	Final state + empty stack
Non-determinism?	Yes	Yes

\*Some PDAs allow multiple symbols at a time, either as input or as stack operations (push, pop). This makes no overall difference.

PDAs can also have "extra" stack symbols not in the input language (Z in JFLAP for instance)

# Pushdown Automata



$L(M) = ??$

PDA6.jff

Assignment Project Exam Help

<https://powcoder.com>

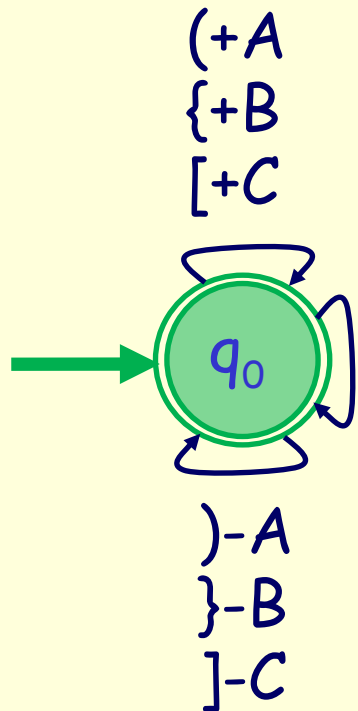
**In:** cc, bbbb, abba, bccb, abccba, bcbabcb...

Add WeChat powcoder

**Out:** ac, bbca, abcb, bbacaaaa, cb, ...

$$L(M) = \{ w \mid w \{a,b,c\}^+, |w| = 2n, w = w^R \}$$

# Pushdown Automata



$L(M) = ??$  PDA7.jff  
~~x.y.z.~~ Assignment Project Exam Help

<https://powcoder.com>

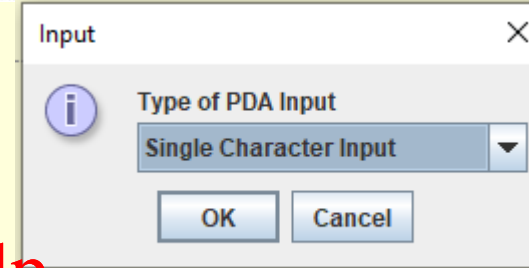
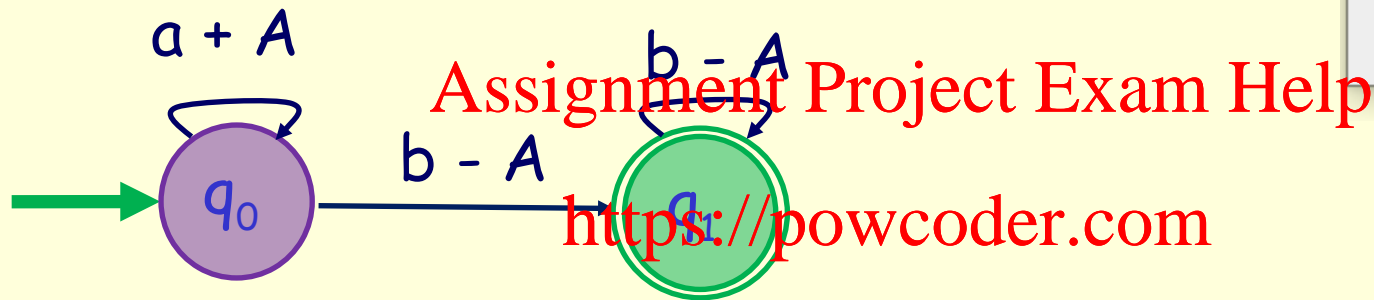
Add WeChat powcoder

$L(M) = \{ w \mid w \text{ has balanced brackets} \}$

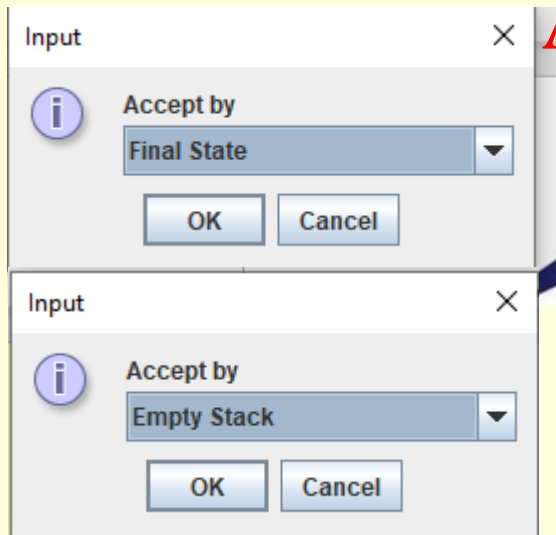
# PDAs in JFLAP

JFLAP does PDAs a little differently ...

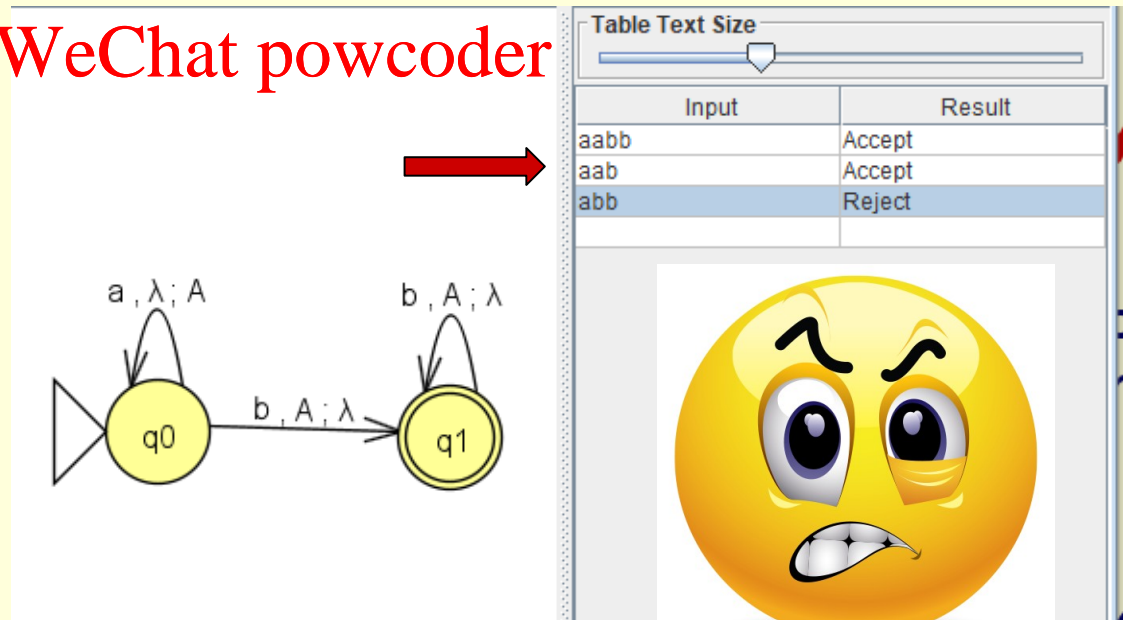
- JFLAP allows multiple inputs per transition
- JFLAP accepts via final state OR empty stack (!!)



Add WeChat powcoder

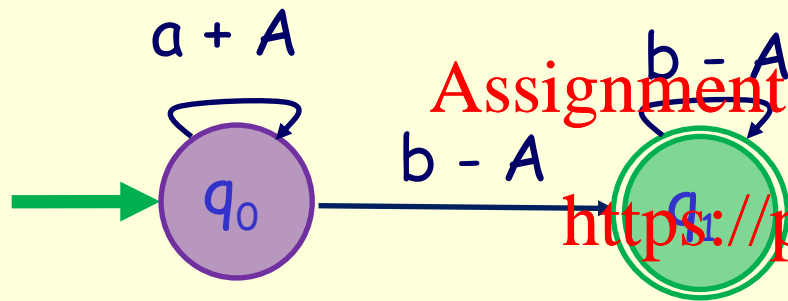
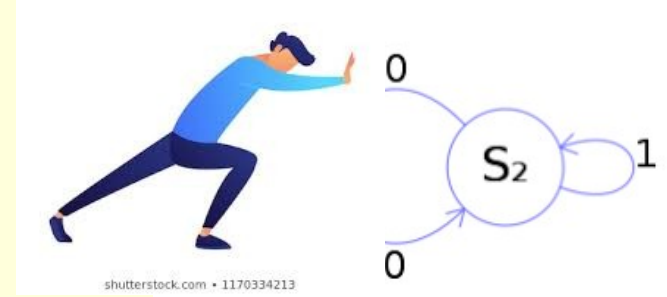


Week 3



# PDAs in JFLAP

JFLAP does PDAs a little differently ...



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

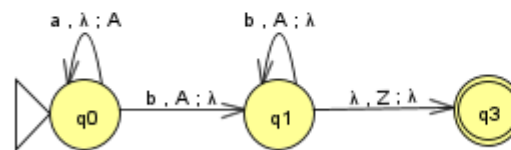
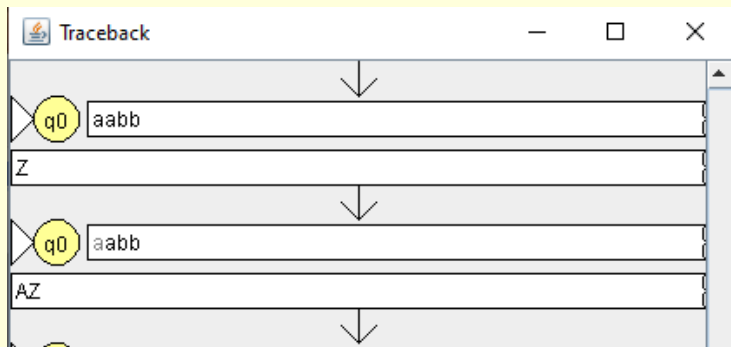
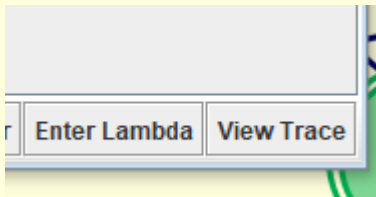
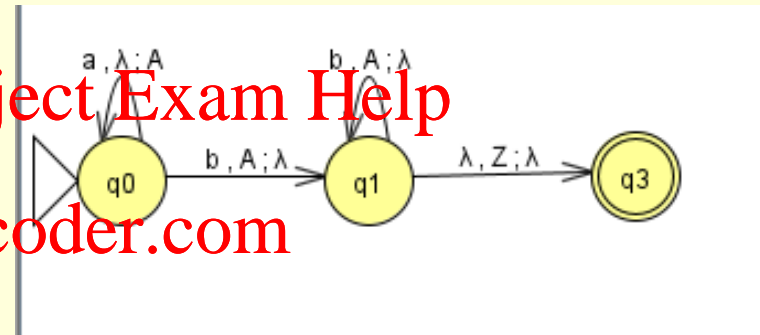


Table Text Size	
Input	Result
aabb	Accept
aab	Reject
abb	Reject



# JFLAP for grammars



JFLAP : <untitled14>

File Input Test Convert Help

Editor

Table Text Size

Start Previous Step Derivation Table

Input 01010

String Accepted

Input Field Text Size (For optimization, move one of the window size adjustors around this wind...)

LHS		RHS
S	→	λ
S	→	ASA
S	→	BSB
S	→	A
S	→	B
A	→	0
B	→	1

Table Text Size

LHS		RHS
S	→	λ
S	→	ASA
S	→	BSB
S	→	A
S	→	B
A	→	0
B	→	1

01010

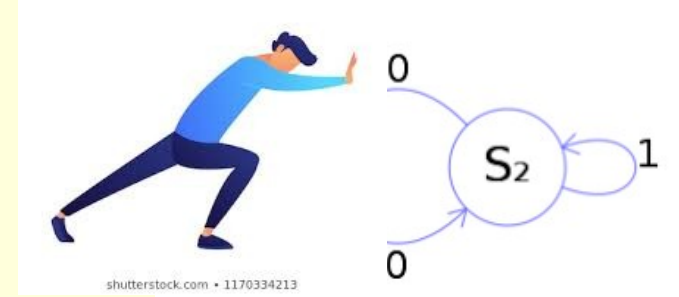
01010

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

# JFLAP

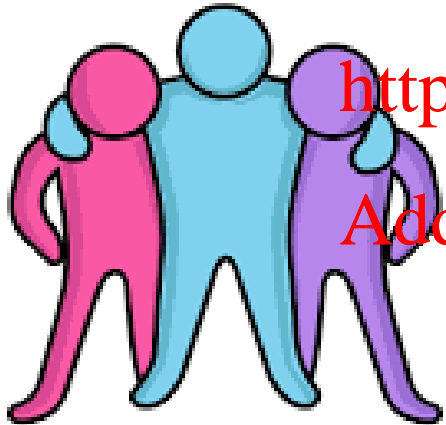


## JFLAP is your friend!

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



Week 3

Computing Theory

# Questions?



Questions?



Assignment Project Exam Help

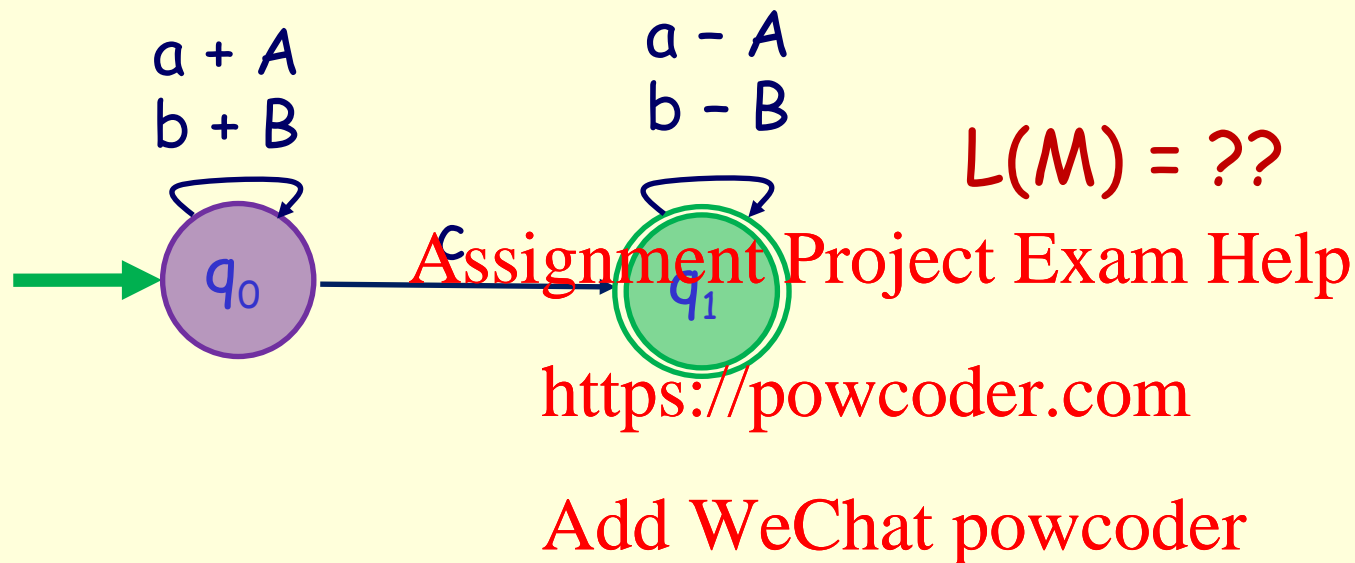
<https://powcoder.com>

Add WeChat powcoder

Questions?



# Pushdown Automata

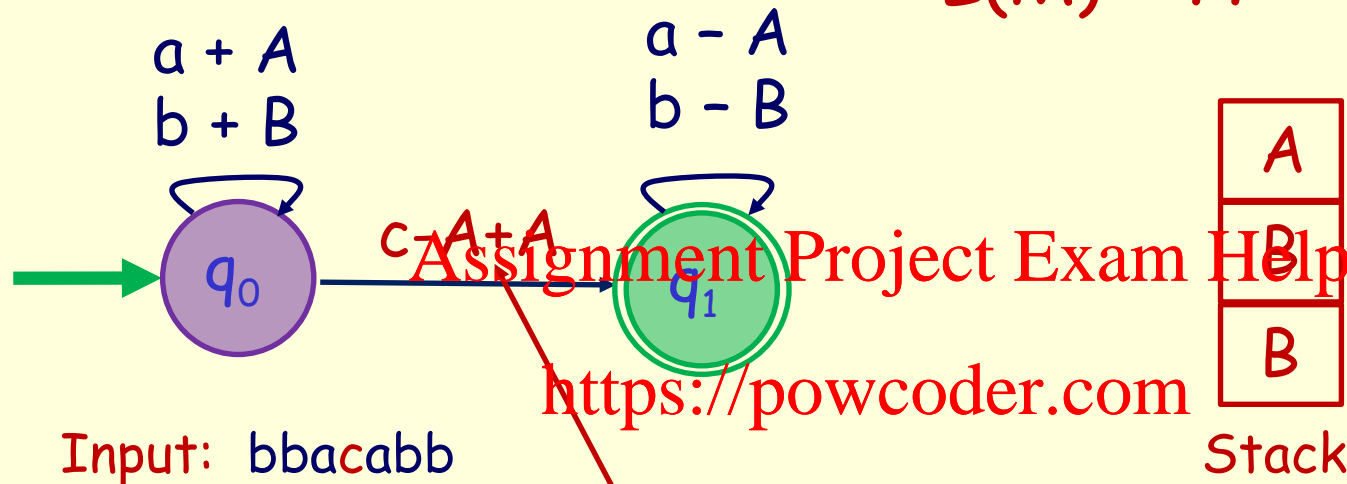


$$L(M) = \{ wcw^R \mid w \{a,b\}^* \}$$

# Pushdown Automata



$L(M) = \dots$



Assignment Project Exam Help

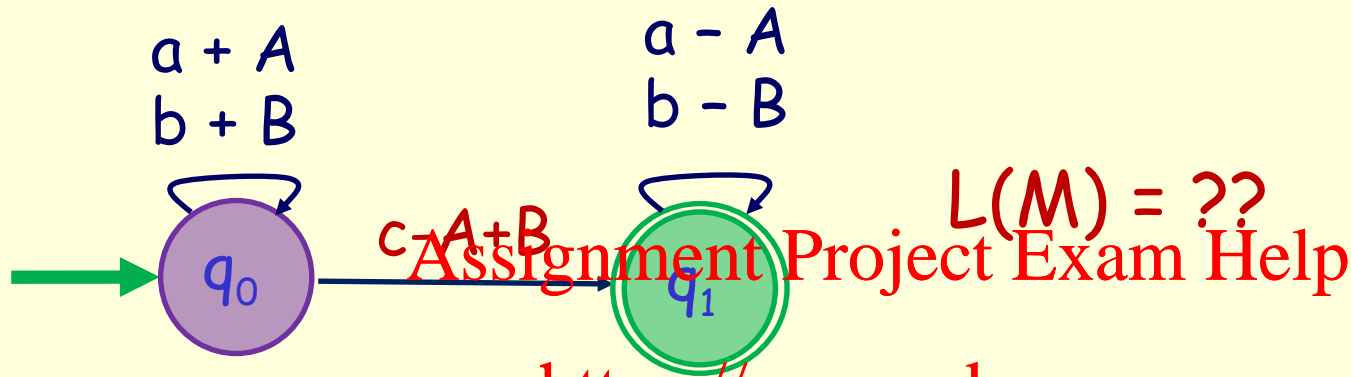
<https://powcoder.com>

Add WeChat powcoder

'only transition if there is an A on the top of the stack. otherwise reject'.

$$L(M) = \{ wacaw^R \mid w \{a,b\}^* \}$$

# Pushdown Automata



Assignment Project Exam Help

[PDA10.jff](#)

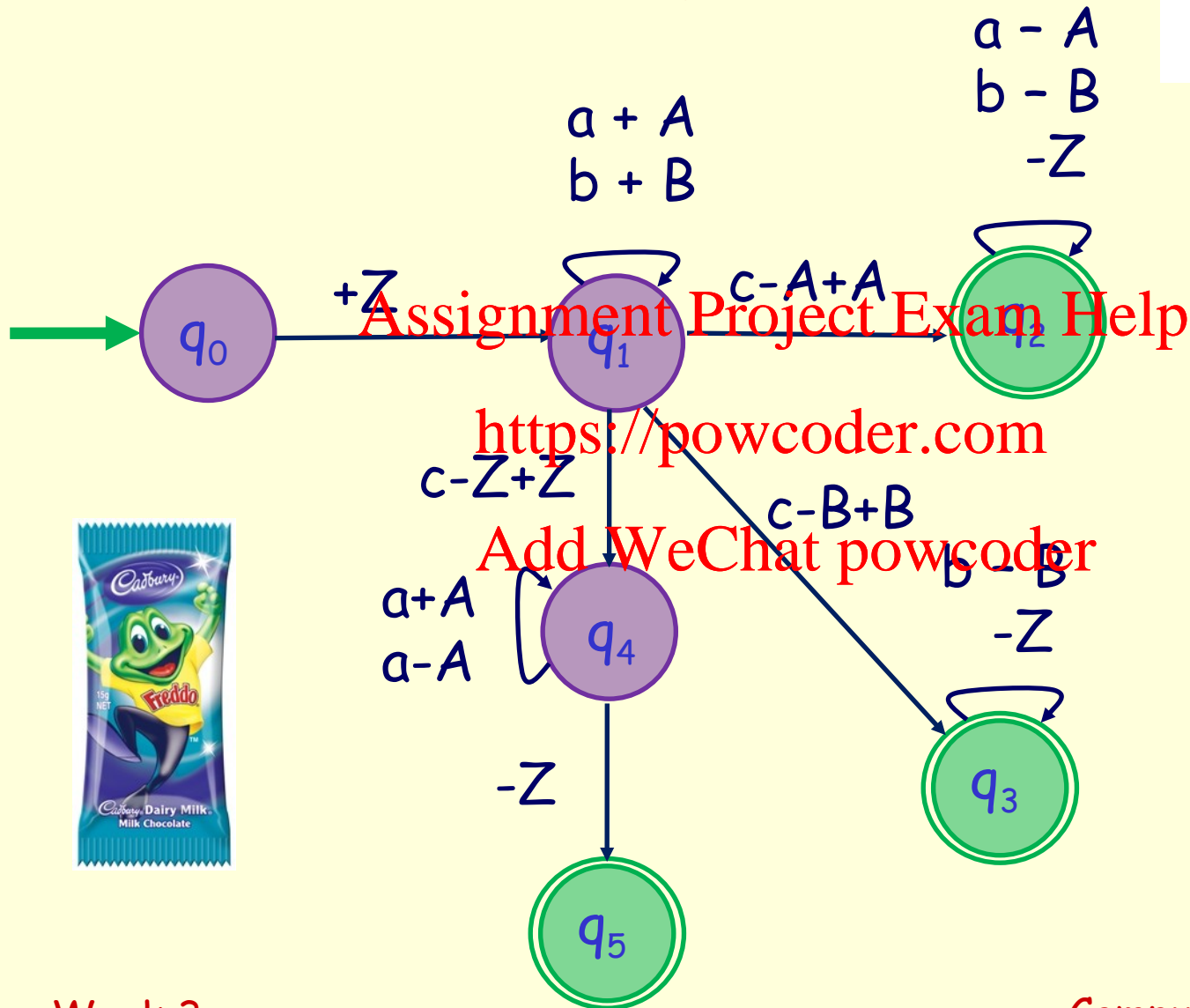
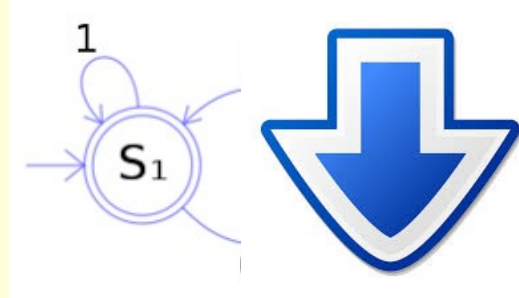
<https://powcoder.com>

Add WeChat powcoder

Can you work out  $L(M)$ ?



# Pushdown Automata



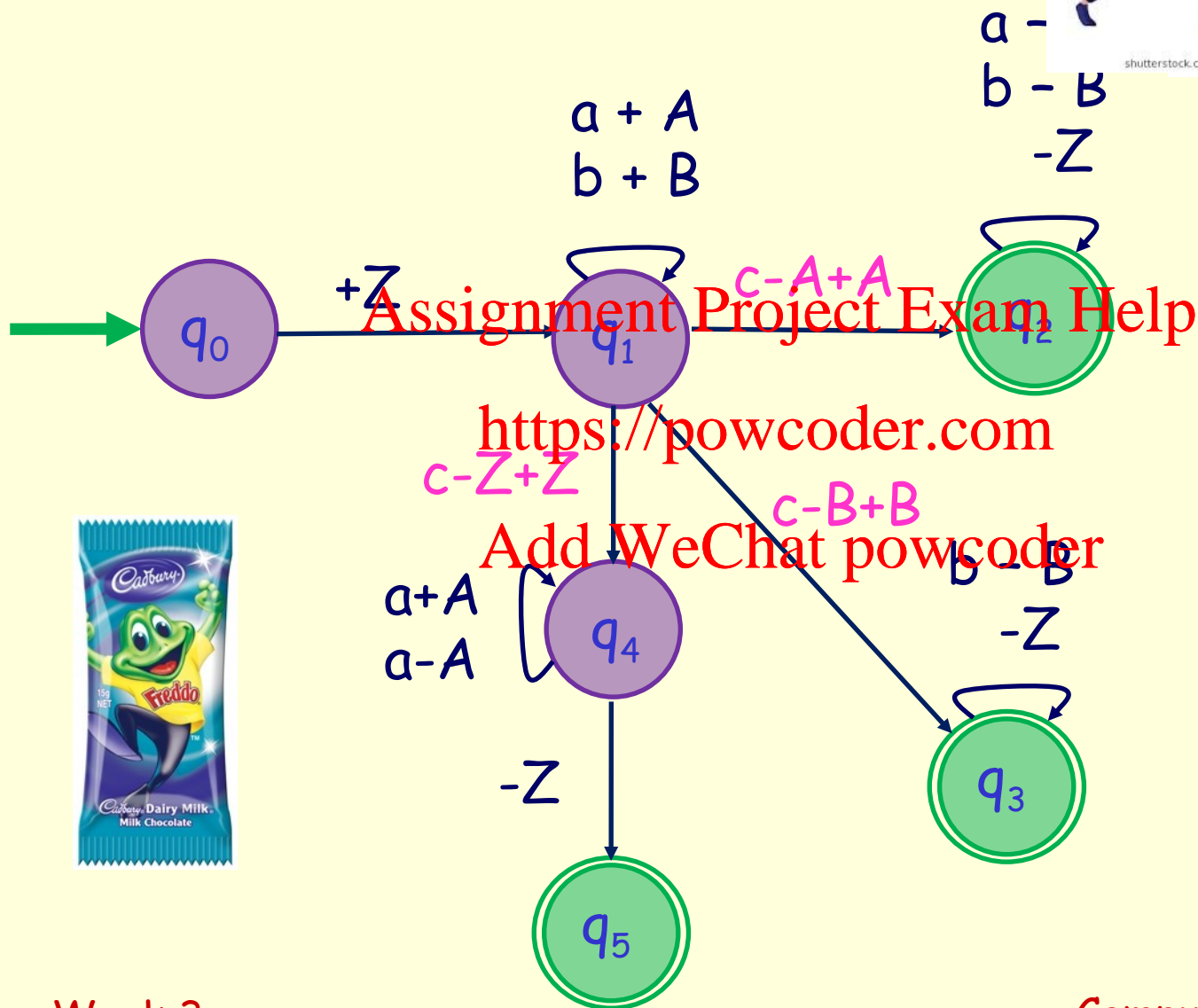
$L(M) = ??$



PDA11.jff



# Pushdown Automata

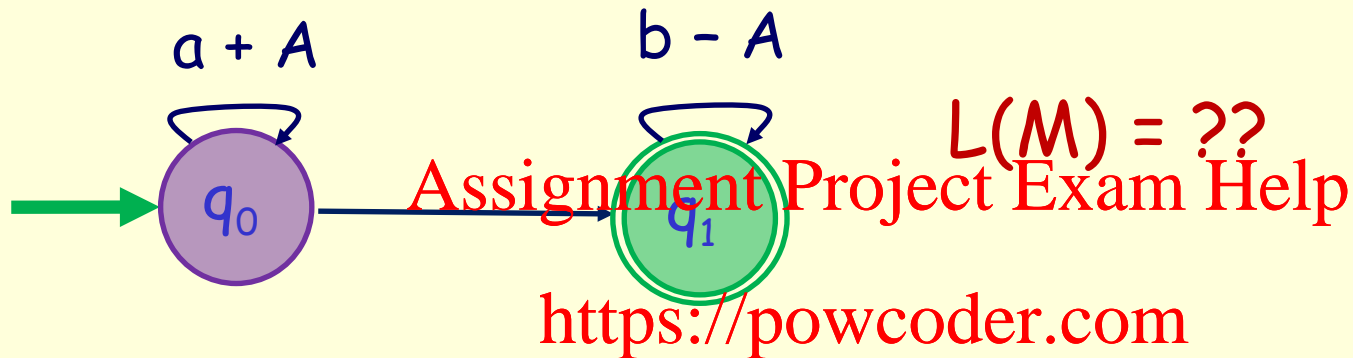


$L(M) = ??$



PDA11.jff

# Pushdown Automata



$$L(M) = \{a^n b^n \mid n \geq 0\}$$

What about  $L = \{a^n b^n c^n \mid n \geq 0\}$ ?

# Questions?



## Questions?



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

## Questions?



Week 3

Computing Theory

A close-up, low-angle shot of a dinosaur's head, likely a Tyrannosaurus Rex, with its mouth wide open, revealing sharp, white teeth and a dark interior. The dinosaur's skin is dark and textured, with visible scales and spines along its back. The background is dark and out of focus, suggesting an indoor setting like a museum or a film set.

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



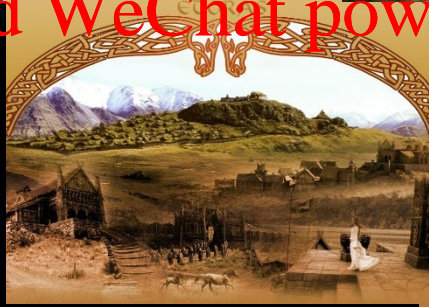
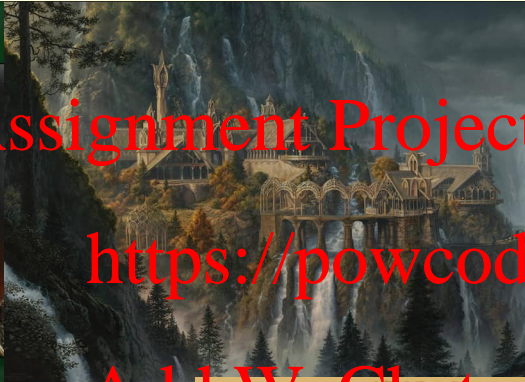
**Break time!** (We resume when all the pictures are gone! This will take 3 minutes!)



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder





Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

I AM BACK!



A detailed illustration of a dragon breathing fire. The dragon is coiled, with its head at the bottom center, mouth wide open, breathing a large plume of bright orange and yellow flames upwards. The dragon's scales are dark and textured, and its eyes are glowing. The background is dark, making the fire and the dragon stand out.

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder



# Alternative Scheme?



Troll	Dreadful	Poor	Acceptable	Exceeds Expectations	Outstanding
-------	----------	------	------------	----------------------	-------------

**Outstanding** - CONGRATULATIONS! Your exemplary powers of deduction and a formidable knowledge of the inner workings of the magical world reveal you to be a witch or wizard of genuine skill and learning.

**Assignment Project Exam Help**

**Exceeds Expectations** - Well done - a most creditable performance!

<https://powcoder.com>

**Acceptable** - demonstrates real magical potential.

**Add WeChat powcoder**

**Poor** - Alas - we regret to inform you that you have narrowly failed. This may have been due to factors outside your control (eg: poltergeist intervention, examination nerves or a malfunctioning quill.) Please do not disconsolate.

**Dreadful** - We are sorry to inform you that you have failed.

**Troll** - You would appear either to have abandoned the test due to factors outside your control (eg, earthquake, poltergeist attack), or else you are a troll, in which case you are to be congratulated on being able to use a computer and have achieved the grade of O.F.T. (Outstanding for Trolls).

**Marking**

**Computing Theory**



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder