# Lab 4: QAOA for MaxCut - Short Assessment

## Objective

Implement the Quantum Approximate Optimization Algorithm (QAOA) to solve a tiny MaxCut problem. Demonstrate an intuitive understanding of QAOA components.

Time: 45 minutes

Points: 25

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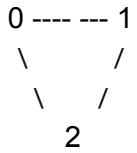
## Part 1: Understanding MaxCut (5 points)

### Problem Setup

Consider this tiny graph with 3 vertices:




Edges: (0,1), (0,2), (1,2)

**Goal: Cut the graph into two sets to maximize the number of edges between sets.**

**Questions:**

1. What is the maximum possible cut value for this graph?
   A) 1
   B) 2
   C) 3
   D) 4
2. Which of these partitions gives the maximum cut?
   A) {0} vs {1,2}
   B) {0,1} vs {2}
   C) {0,2} vs {1}
   D) All give the same value

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## Part 2: QAOA Circuit Construction (10 points)

### Instructions

Complete the Python code below to build a 2-layer QAOA circuit (p=2) for the MaxCut problem.

## Part 3: Intuitive QAOA Explanation (5 points)

Briefly explain in your own words:

1. What does the cost Hamiltonian H_C represent in MaxCut?
   *(2 points)*
2. Why do we start with the |+⟩^⊗n state?
   *(1 point)*
3. What's the purpose of alternating between cost and mixer unitaries?
   *(2 points)*

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## Part 4: Parameter Optimization & Results (5 points)

Coding lab is located in https://github.com/learningdungeon/qamp-2025
folder of assessments > coding_tasks > tier4> QAOA_Assessement

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## Submission Requirements

Submit a single Python file containing:

1. Completed code with all `# YOUR CODE HERE` sections filled
2. Answers to all questions as comments
3. Output from running your code

Example format:

```
python
```

```
# Part 1 Answers:
# 1. C) 3
# 2. D) All give the same value (explanation: each partition cuts 2 edges)

# Part 3 Answers:
# 1. H_C encodes the cut value...
# 2. We start with |+⟩^⊗n because...
# 3. Alternating explores...

# Part 4 Answers:
# 1. Most frequent: '101'
# 2. Yes, '101' means vertices 0 and 2 in one set, 1 in other → cuts edges
(0,1) and (1,2)
```

```
# 3. Approximation ratio: 2.4/3 = 0.8
```

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## Rubric

| Section | Points | Criteria |
|---|---|---|
| Part 1 | 5 | Correct answers with brief explanation |
| Part 2 | 10 | Complete, working QAOA circuit |
| Part 3 | 5 | Clear, intuitive explanations |
| Part 4 | 5 | Correct evaluation and analysis |
| Total | 25 | |

Bonus (2 points): Suggest how you would optimize γ and β parameters for better results.

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## Quick Reference

### QAOA Steps for MaxCut:

1. Initial state: H⊗ⁿ|0⟩^⊗n = |+⟩^⊗n
2. Cost unitary: Apply RZZ(-2γ) for each edge (i,j)
3. Mixer unitary: Apply RX(2β) to each qubit
4. Repeat steps 2-3 for p layers
5. Measure in computational basis

## Key Insight:

- Each qubit = graph vertex (0 or 1 = which set)
- Edge contributes +1 if vertices are in different sets
- QAOA optimizes γ,β to maximize expected cut value

Time's up! Submit your work.