

CSCI 5370 Quantum Computing

(Spring 2025)

Week 1

Instructor : Xiao Liang

Course homepage: [https://xiao-liang.github.io/  
Resources/Courses/CSCI5370-Spring25.html](https://xiao-liang.github.io/Resources/Courses/CSCI5370-Spring25.html)

## About the Instructor:

Why's a cryptographer teaching  
CSCI 5370 Quantum Computing ?

- Quantum cryptographers know QC very well, sometimes even better than QC experts.
- Quantum cryptography is a flagship app. of QC. (You'll see it this semester)
- Boundary between QC and Quantum cryptography is blurred.

Today's Agenda:

① Introduction & administrative.

② Qubits, One-qubit System.

# Motivation.

- What is QC
- Why is QC useful? Applications?
- state-of-the-art quantum computers?  
E.g. IBM's, Google's.

Won't waste time on them...  
not in a postgraduate course.

On-line resource:

On-line resources for that:

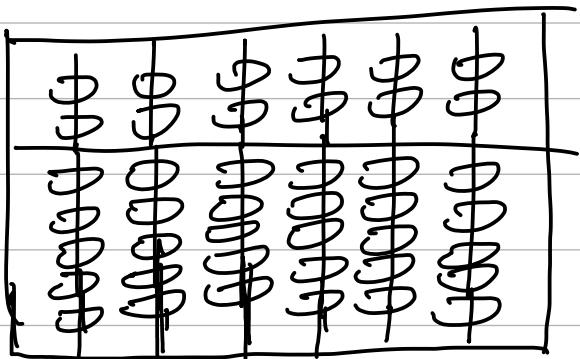
- The first lecture of Henry Yuen's course: <https://www.youtube.com/watch?v=X2vJGA1yFrs>

QC in contrast to "Classical" Computing.

Essence of any computing device:

(e.g. abacus, calculator, laptop...)

- encoding
- manipulating



mechanical  
computing device

physics

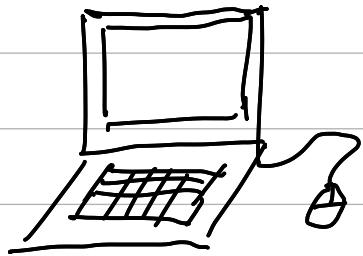
logic

Classical mechanics

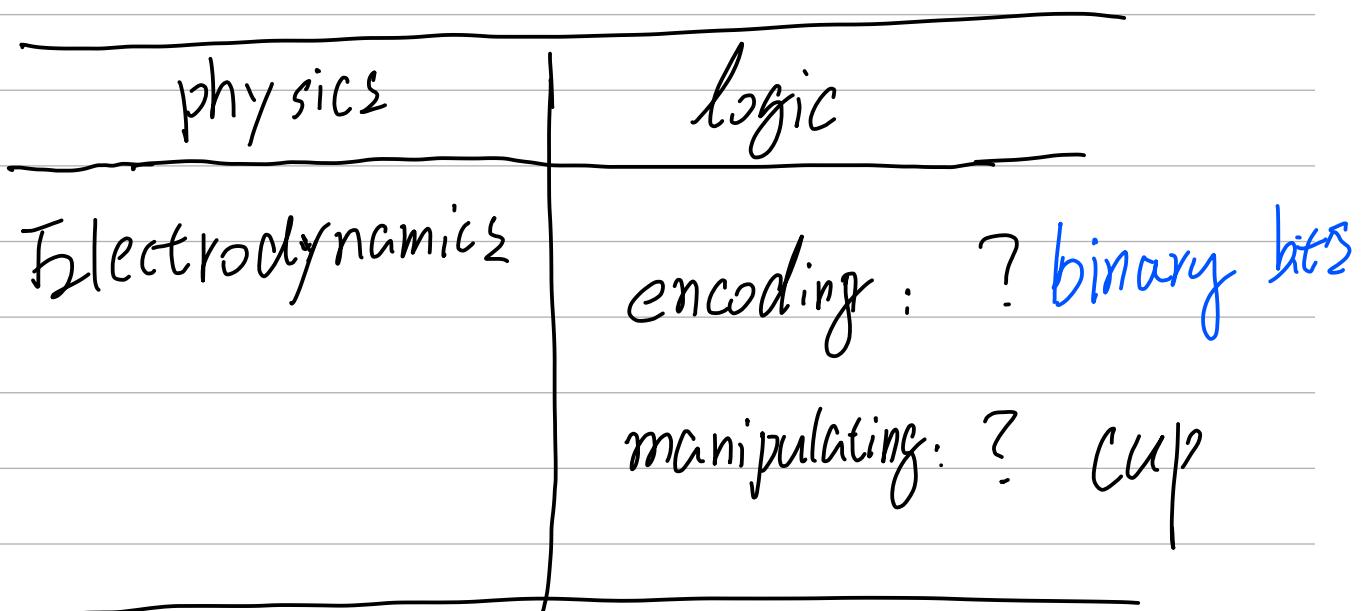
encoding: ?

$$\vec{F} = \frac{d}{dt} \vec{P}$$

manipulating: ?



electrical  
computing device

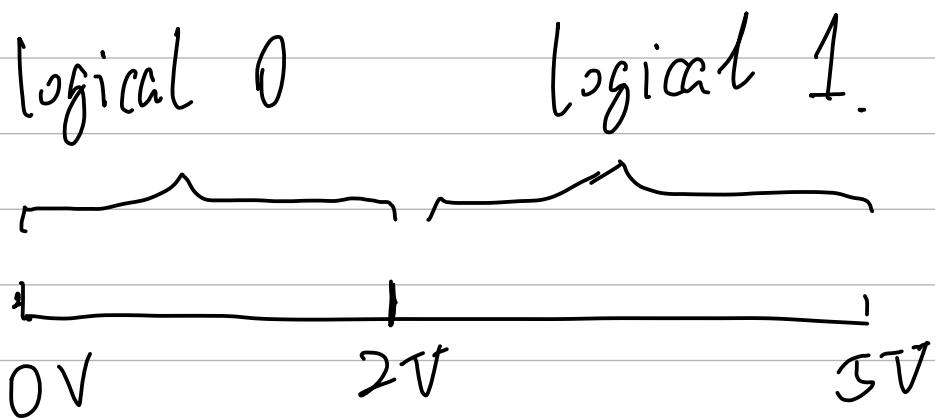


$$\left\{
 \begin{array}{l}
 \nabla \cdot \mathbb{E} = \frac{\rho}{\epsilon_0} \\
 \nabla \cdot \mathbb{B} = 0 \\
 \nabla \times \mathbb{E} = \frac{\partial}{\partial t} \mathbb{B} \\
 \nabla \times \mathbb{B} = \mu_0 (\mathbf{J} + \epsilon_0 \frac{\partial}{\partial t} \mathbb{E})
 \end{array}
 \right.$$

Maxwell's Equations

Voltage levels to represent bits :

Voltage level :



$$1.9999 \text{ V} \sim 2.0001 \text{ V}$$



Error Correcting Code

## Summary:

$$\text{Computing device} = \boxed{\begin{array}{l} \text{A set of rules:} \\ \{ \text{encoding} \\ \text{manipulating} \end{array}} + \boxed{\begin{array}{l} \text{The physics} \\ \text{implementing the} \\ \text{rules} \end{array}}$$

Let's use this formula to approach  
Quantum Computing !

physics	logic
$i\hbar \frac{\partial}{\partial t}  \psi\rangle = \hat{H}  \psi\rangle$	encoding : qubits manipulating: "4 postulates of QM"

# Scope of CSCI 5370:

- The "logic" part.
- Use quantum mechanics as axioms.
  - no explanation (cost a 2-semester course of QM)
- Get you familiar with { encoding  
[ manipulating

Do interesting things with them

(Course homepage for topics)

(Conceptual)

Learning outcome (See course homepage)

- how QC differs from "classical" comp.
- Get an idea of the SOTA of theoretical QC
- Big questions and research opportunities
- Interdisciplinary.

Who this course is NOT for:

- People who want to learn how to build a quantum computer.
- People who want to learn QM.

Prerequisites:

- "Hard" prerequisites:
  - Linear algebra
  - Probability theory
- "Soft" prerequisites:
  - Algorithm (Design & analysis)
  - Computational Complexity  
(Theory of Computation)

## Administrivia:

Grading {

homework	30%
midterm	30%
Project	40%

### Homework: (30%)

- Weekly Workload: recall your undergrad Calculus / Linear Algebra / Probability)
- two types:
  - ① Reading Assignments:
    - preview of next lecture topics
    - supplementary reading materials of lecture topics
  - (I have no way to check this part)

## ② "Standard" problem-solving assignments:

- Practice your "quantum calculation" skills
- Complete missing steps in lecture proofs.
- Submission MUST be in LaTeX code.

Midterm: (30%)

- Same style as Problem-Solving assignments.
- I don't test your memory.

(Necessary formulas will be provided  
on the exam sheet.)

I'm also considering open-book exam.)

## Project : (40%)

- 4 - 5 people per group.
- choose a QC-related topic.
  - I'll provide a list of topics.
  - Talk to me if you have your own .
- Write a paper on the chosen topic:
  - Literature survey.
  - Systematization of knowledge (SOK)
  - Pedagogical explanation of a published paper.
  - Anything that convinces me that you've learned something new, related to Q.C.
  - If you solve an open problem, you'll get A regardless of your other performance.

- Run a mock Conference:
  - Say we have 10 groups. (thus 10 papers)
  - Each group choose 4-6 papers.
    - Read them
  - Write reviewers' comments
  - Grade them.
- 3-5 papers with highest scores will win the "Best Paper Award":
  - Bonus points to group members final grades
  - Give a 45-min talk to the class.

[Don't worry. I'll provide step-by-step instructions when the project starts.]

# A Project - Oriented Perspective of CSCI 5370

All we learn is for the final Project.

① First half of the course:

- Basic skills of QC.

② Second half of the course:

- Examples how other people do their "projects"

③ Final Project of CSCI 5370:

- Do your own project.

Final Goal:

Bring QC skills to your own  
research / job / project

## Text book:

- No official textbook
- Will assign different chapters from diff. books as reading assignment.
- See course homepage for a recommended reading list.

## TA and Office hour,

- Mr. LUO, Robin Bin

- Tue 2:30 - 3:30 pm

Room 120, Ho Sin Hang Engineer Bldg.