INTRO TO QUANTUM COMPUTING

Lab #2

TRIGONOMETRY AND COORDINATE SYSTEMS

Sarah Muschinske

10/28/2020

© 2020 The Coding School

PROGRAM FOR TODAY

- Ground rules
- Pre-lab student feedback
- Popular questions from last week
- Lab content
- Post-lab student feedback

© 2020 The Coding School

GROUND RULES

- We want to ensure that every student participating in this lab feels welcome and included

- We ask that you:
  - **Do not** spam the chat or Q&A with repeated questions or messages
  - **Do not** put answers to problems in the chat or Q&A, **unless your TA asks you to**
  - **Keep your questions relevant** to the topics being discussed. We have Piazza for other content-related questions, and Discord for questions on logistics
  - Only raise your hand if the TAs ask students to

© 2020 The Coding School

GROUND RULES

- As instructors and TAs, we want to hear from diverse voices
  - **Step up, step back**

- We will not be able to address all content-questions in lecture or lab
  - Look at answers to similar questions on Piazza or Discord
  - Post your question in the relevant folder **in Piazza** (e.g. week 1)
  - We will continue to explore new content each week, and will likely answer your question in future weeks! Hold on ☺

© 2020 The Coding School

PRE-LAB CANVAS FEEDBACK

- Please log into Canvas and answer your lab section's quiz (using the password posted below and in the chat).
  - This is lab number **7**
  - Password: 5084
- On a scale of 1 to 5, how would you rate your understanding of this week's content?
  - 1 –Did not understand anything
  - 2 – Understood some parts
  - 3 – Understood most of the content
  - 4 – Understood all of the content
  - 5 – The content was easy for me/I already knew all of the content

- **This quiz is also your lab attendance!**

© 2020 The Coding School

QUESTIONS FROM PAST WEEK

- Combinations of logic expressions: (A NAND B) XOR C

$[0,1] \rightarrow 2^3 = 8$

A	B	C	out
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

© 2020 The Coding School

QUESTIONS FROM PAST WEEK

- How are logic gates made? What's inside them?

- Transistors!
  - A transistor is a switch that can electronically turn a current ON (1) or OFF (0)
  - Gates are made using one or more such switches
  - Many gates are combined to make larger logic circuits
  - Many such logic circuits are combined to make a (classical) computer

MOSFET

BJT

© 2020 The Coding School

LEARNING OBJECTIVES FOR LAB 2

- Analyze trigonometric functions at various angles
  - Finding values of sin, cos, tan
- Solidify understanding of coordinate systems
  - Cartesian coordinates
  - Polar coordinates
  - Conversion between the two systems
- Summation notation*

*Optional content

© 2020 The Coding School

TRIGONOMETRIC FUNCTIONS

Unit circle: Circle of radius 1

$\sin(\theta) = y$

$\cos(\theta) = x$

$\tan(\theta) = \frac{y}{x}$

© 2020 The Coding School

HOW TO CALCULATE SINES AND COSINES?

© 2020 The Coding School

HOW TO CALCULATE SINES AND COSINES?

- Measure on unit circle

- Lookup table (or slide rule)

- Plug into calculator

- Taylor expansion

radians

$$\sin(x) = x - \frac{x^3}{6} + \frac{x^5}{120} - \frac{x^7}{5040} + \cdots$$

$$cos(x) = 1 - \frac{x^2}{2} + \frac{x^4}{24} - \frac{x^6}{720} + \cdots$$

© 2020 The Coding School

ANNOTATED UNIT CIRCLE

© 2020 The Coding School

SINE AND COSINE

© 2020 The Coding School

TRIGONOMETRIC FUNCTIONS

π radians $= 180^\circ$ $\quad 30^\circ = \dfrac{\pi}{6}$ radians

$$1 = \sqrt{\left(\frac{\sqrt{3}}{2}\right)^2 + \left(\frac{1}{2}\right)^2}$$
$$= \sqrt{\left(\frac{3}{4} + \frac{1}{4}\right)}$$
$$= 1$$

$$\sin\left(\frac{\pi}{6}\right) = \frac{1}{2}$$

$$\cos\left(\frac{\pi}{6}\right) = \frac{\sqrt{3}}{2}$$

$$\tan\left(\frac{\pi}{6}\right) = \frac{y}{x} = \frac{1}{\sqrt{3}} \times \underbrace{\frac{\sqrt{3}}{\sqrt{3}}}_{=1} = \frac{\sqrt{3}}{3}$$

© 2020 The Coding School

TRIGONOMETRIC FUNCTIONS

$$30^{o} = \frac{\pi}{6} \text{ radians}$$

$$\sin\frac{\pi}{6} = \frac{1}{2}$$

$$\cos\frac{\pi}{6} = \frac{\sqrt{3}}{2}$$

$$\tan\frac{\pi}{6} = \frac{1}{\sqrt{3}}$$

© 2020 The Coding School

TRIGONOMETRIC FUNCTIONS

$$240^{\circ} = \frac{4\pi}{3} \text{ radians}$$

$$\sin\left(\frac{4\pi}{3}\right) = -\frac{\sqrt{3}}{2}$$

$$\cos\left(\frac{4\pi}{3}\right) = -\frac{1}{2}$$

$$\tan\left(\frac{4\pi}{3}\right) = \sqrt{3}$$

© 2020 The Coding School

TRIGONOMETRIC FUNCTIONS

$$240^{\circ} = \frac{4\pi}{3} \text{ radians}$$

$$\sin\frac{4\pi}{3} = -\frac{\sqrt{3}}{2}$$

$$\cos\frac{4\pi}{3} = -\frac{1}{2}$$

$$\tan\frac{4\pi}{3} = \sqrt{3}$$

© 2020 The Coding School

QUESTIONS

Bloch sphere

$x = \cos(\theta)$
$y = \sin(\theta)$

Questions on content so far?

© 2020 The Coding School

COORDINATE SYSTEMS

© 2020 The Coding School

COORDINATE SYSTEMS

© 2020 The Coding School

CARTESIAN COORDINATE SYSTEM

© 2020 The Coding School

CARTESIAN COORDINATE SYSTEM

© 2020 The Coding School

CARTESIAN COORDINATE SYSTEM

© 2020 The Coding School

POLAR COORDINATE SYSTEM

$$\theta = \arctan\left(\frac{y}{x}\right)$$

$$\tan(\theta) = \frac{y}{x}$$

$$\arctan(\tan(\theta)) = \theta$$

$$r^2 = x^2 + y^2$$

$$r = \sqrt{x^2 + y^2}$$

$$= \sqrt{16 + 9}$$

$$r = \sqrt{25} = 5$$

© 2020 The Coding School

CONVERTING CARTESIAN TO POLAR

$$\underset{\text{cartesian}}{(x, y)} \rightarrow \underset{\text{polar}}{(r, \theta)}$$

© 2020 The Coding School

CONVERTING CARTESIAN TO POLAR

$$\underset{\text{cartesian}}{(x, y)} \rightarrow \underset{\text{polar}}{(r, \theta)}$$

$$r = \sqrt{x^2 + y^2}$$

$$\theta = \tan^{-1}\frac{y}{x}$$

arctan

© 2020 The Coding School

POLAR COORDINATE SYSTEM

© 2020 The Coding School

CONVERTING POLAR TO CARTESIAN

$$\underset{\text{polar}}{(r, \theta)} \rightarrow \underset{\text{cartesian}}{(x, y)}$$

© 2020 The Coding School

CONVERTING POLAR TO CARTESIAN

$$\underset{\text{polar}}{(r, \theta)} \rightarrow \underset{\text{cartesian}}{(x, y)}$$

$$x = r \cos \theta$$

$$y = r \sin \theta$$

© 2020 The Coding School

EXAMPLE OF POLAR → CARTESIAN

$$(r, \theta) \rightarrow (x, y)$$

polar cartesian

$$x = r\cos\theta$$

$$y = r\sin\theta$$

© 2020 The Coding School

UNIT CIRCLE

$x = \frac{5}{2}$

$y = \frac{\sqrt{3} \times 5}{2}$

$r = \cancel{1}\ 5$

$\theta = \frac{\pi}{3}$

$x = r\cos(\theta)$

$y = r\sin(\theta)$

© 2020 The Coding School

EXAMPLE OF POLAR → CARTESIAN

$$(r, \theta) \rightarrow (x, y)$$

polar cartesian

$$x = r\cos\theta$$
$$y = r\sin\theta$$

© 2020 The Coding School

QUESTIONS

$|0\rangle$, $|1\rangle$

Questions on content so far?

© 2020 The Coding School

POST-LAB ZOOM FEEDBACK

- Please answer the Zoom poll
- On a scale of 1 to 5, how would you rate your understanding of this week's content?
  - 1 –Did not understand anything
  - 2 – Understood some parts
  - 3 – Understood most of the content
  - 4 – Understood all of the content
  - 5 – The content was easy for me/I already knew all of the content

© 2020 The Coding School

ADDITIONAL OPTIONAL CONENT

© 2020 The Coding School

SUMMATION NOTATION

Notation to make writing long sums easier!

© 2020 The Coding School

SUMMATION NOTATION

Notation to make writing long sums easier!

$$\text{Sum} = 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10$$

© 2020 The Coding School

SUMMATION NOTATION

Notation to make writing long sums easier!

$$\text{Sum} = 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10$$

$$\text{Sum} = \sum_{i=1}^{10} i$$

© 2020 The Coding School

SUMMATION NOTATION

Notation to make writing long sums easier!

$$\text{Sum} = 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10$$

$$\text{Sum} = \sum_{i=1}^{10} i$$

$$a_1 + a_2 + a_3 + a_4 + a_5 = \sum_{k=1}^{5} a_k$$

© 2020 The Coding School

TRIGONOMETRIC FUNCTIONS

$$120^{\circ} = \frac{2\pi}{3} \text{ radians}$$

© 2020 The Coding School

TRIGONOMETRIC FUNCTIONS

$$120^{\circ} = \frac{2\pi}{3} \text{ radians}$$

$$\sin\frac{2\pi}{3} = \frac{\sqrt{3}}{2}$$

$$\cos\frac{2\pi}{3} = -\frac{1}{2}$$

$$\tan\frac{2\pi}{3} = -\frac{1}{\sqrt{3}}$$

© 2020 The Coding School