Final Exam 2021

ⓘ This is a preview of the published version of the quiz

Started: May 6 at 3:58pm

Quiz Instructions

See Final Instructions: https://www.seas.upenn.edu/~ese150/spring2021/final_details.pdf

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For this exam, we will use what you learn from the course to design a simple, whistle-controlled robotic dog.

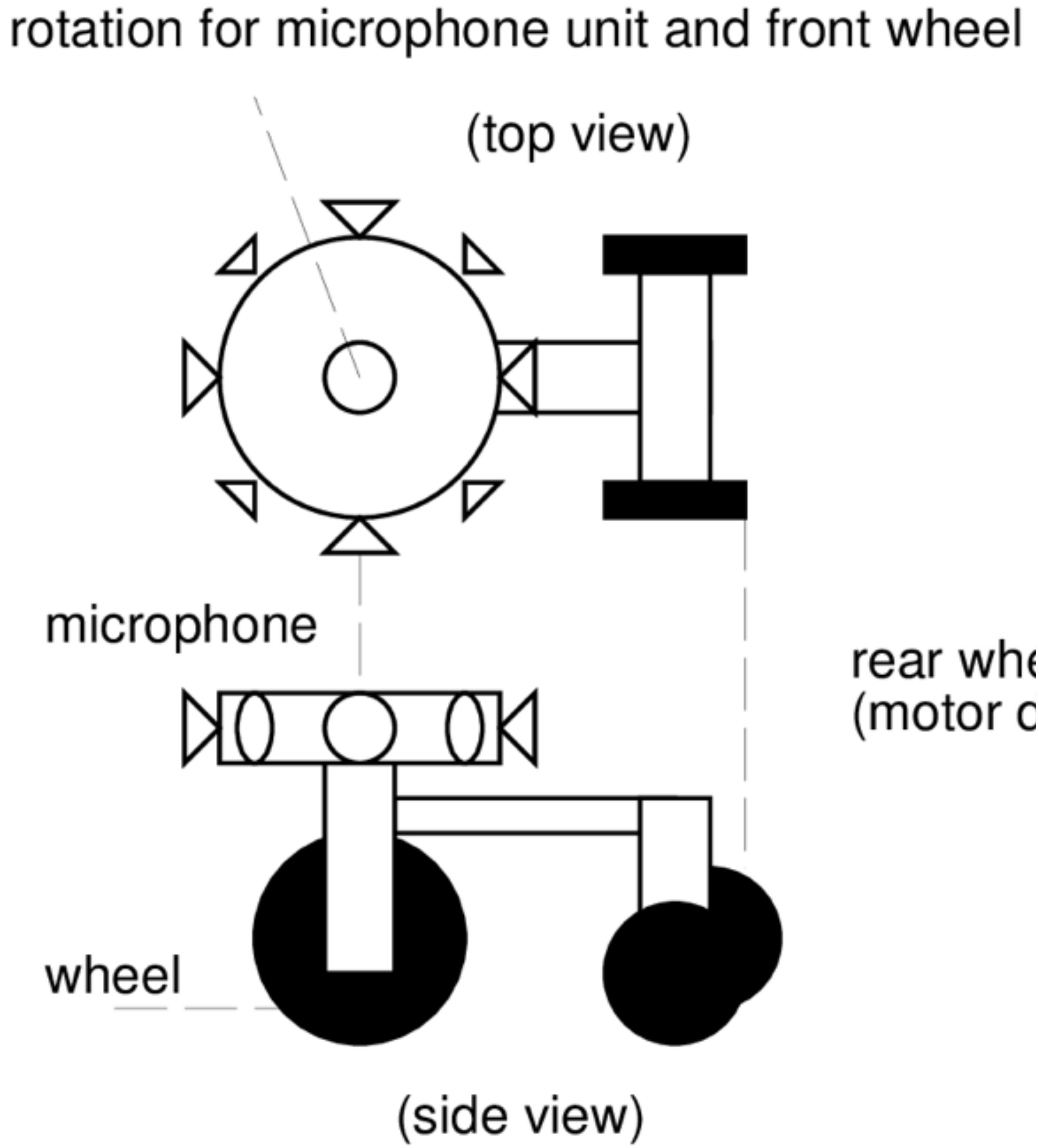
The basic robot will work like a tricycle where we replace the handlebars with a "head" cylinder.

Here's a picture of a child's tricycle from Hatena Fotolife https://commons.wikimedia.org/wiki/File:Tricycle_icon.jpg (https://commons.wikimedia.org/wiki/File:Tricycle_icon.jpg)

The head has N microphones mounted at even intervals facing outward.

The head is servo-controller to rotate around a central poll connected to the front wheel, such that turning the head turns the front wheel.

A motor drives the back wheels. It can be off or turned on at some speed to rotate the wheels forward or backward. Both back wheels turn together. Steering is provided by the servo-controlled front wheel.



Question 1

5 pts

Assume the servo can be rotated 0 to 360 degrees with 7b worth of control, what is maximum absolute error between an intended angle and the angle you can express to the servo? Express your answer in degrees.

Question 2

5 pts

How do you extract the loudness of frequency components at the microphone using a microcontroller like the Arduino/ItsyBitsy used in lab?

That is, the microphone is connected to an analog input pin to the microcontroller. The analog input can be read to produce a 8b digital number.

You want to know the loudness of a frequency (or set of frequencies). The loudness of a frequency set is the minimum magnitude of the frequencies in the set.

How can you use the microcontroller to compute the loudness of the frequency (set)?

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Question 3

5 pts

Assume the ItsyBitsy take 10 microseconds to read one analog value from one of its inputs.

Just based on this read time and the 20KHz sampling rate, what is the upper bound on the number of sensors the single ItsyBitsy support?

Question 4

5 pts

Assume we sample at 20KHz and operate on 25ms windows for frequency detection.

(assume analog filtering of input is set at the appropriate level to prevent aliasing.)

Per frequency whose loudness we would like to extract, how many multiply operations will be required to compute the magnitude of the frequency?

Question 5

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Question 6

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Question 7

5 pts

Using the loudness inputs, we can orient the robot dog toward the source. Question 12 below develops further details of a potential implementation.

As the robot dog moves, the limit in sensing resolution and servo position mean it may not be headed exactly toward the source. Further, disturbances as it travels may also drive it off course.

Assuming the whistle continues and the robot continues to orient its head as outline above, will the robot dog be effective at moving closer to the whistle source? why or why not?

[for simplicity, assume no obstacles in the robot dog's path to whistle]

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Question 8

5 pts

Continue to assume the ItsyBitsy take 10 microseconds to read one analog value from one of its inputs.

Further assume the ItsyBitsy runs at 100MHz and can perform a single multiplication and the other (non-multiply) operations associated with each multiple in 100 cycles. If we need to extract the amplitude of 4 tones from each microphone, how many microphone sensors can a single ItsyBitsy support?

Question 9

5 pts

Once oriented, it should only be necessary to listen to the position 0 microphone.

Using the same analogRead time (10 microseconds) and processing assumptions (100MHz operation, 100 cycles for all the work associated with each multiply), how many distinct tones, T, can the ItsyBitsy extract from a single microphone?

Question 10

0 pts

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Question 11

0 pts

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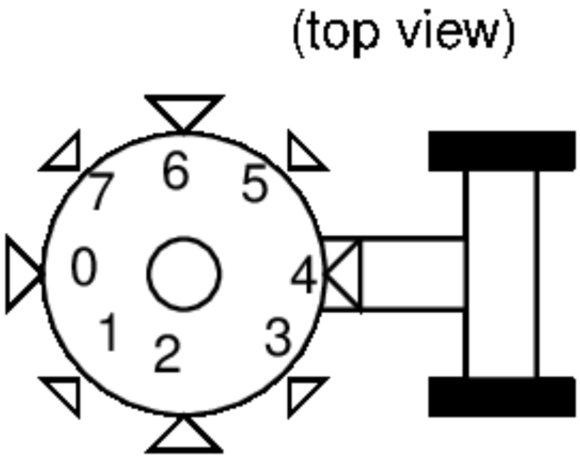
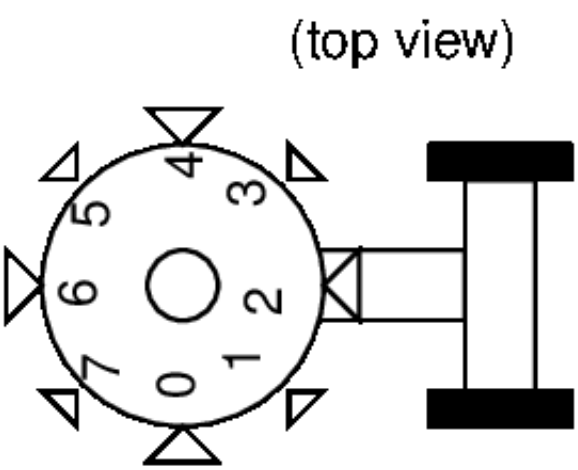
Question 12

10 pts

Provide multiplexer logic for control to orient the front wheel (microphone position 0) to face the whistle sound for an N=8 design.



When servo is at 0 or 360 degrees,
wheel is straight front–to–back
and microphone at position 0 faces front.



When servo is at 90 degrees,
wheel (whose front is aligned with position 0)
is pointed to the left (shown bottom of pix here).

When servo is between 90 and 270 degrees, the rear wheels turn backwards. Otherwise, they turn forward.

The basic strategy is this:

- When the microphone at position 0 is not receiving the loudest sound, first try to turn so that the position 0 microphone is loudest
- When the microphone at position 0 is receiving the loudest sound, record the loudness at +6 degrees and -6 degrees, and use that information to decide which way the servo should move to increase the loudness at position 0

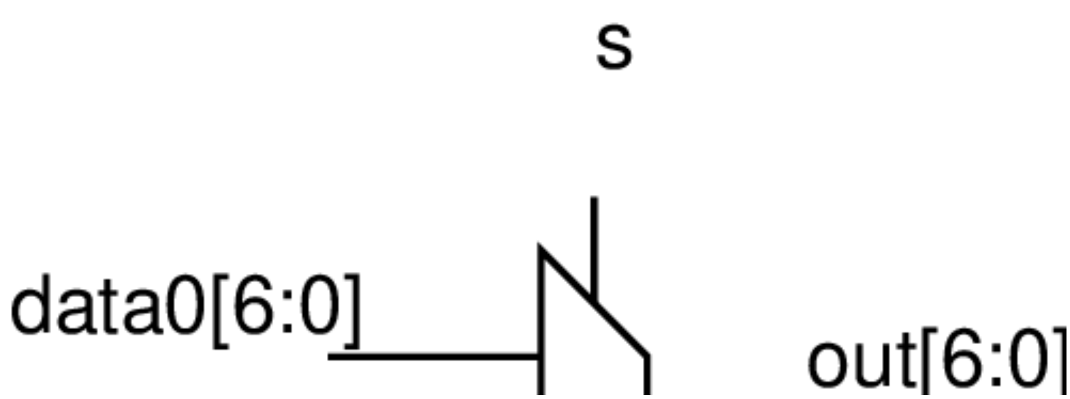
We assume throughout that a microphone that is closer to the whistle source hears a louder sound. We also assume that a microphone's angle relative to a source impacts loudness. One pointed directly at the source hears the loudest sound, and this decreases as the angle increases between the source and the microphone direction.

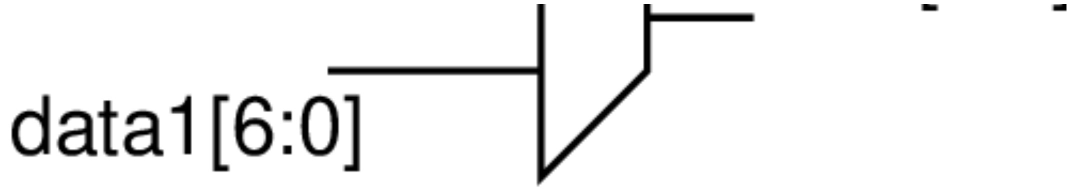
To simplify, we assume there is external logic to get the +6 and -6 readings, and you just need to show how to put this information together to produce the new position control for the servo.

Build your logic out of 2-input multiplexers. For simplicity, you will be switching 7b values, so your basic building block is a 2-input multiplexer that takes a 0 or 1 control input (1 bit) and produces 7b output, either the 7b value on the data0 input or the 7b value on the data1 input.

Each multiplexer behaves as follows:

if (s) out[6:0]=data0[6:0] else out[6:0]=data1[6:0]





For drawings, you may use the mux icon above.

You may describe a mux in text using:

out=mux(s,data0,data1);

You may provide constants for any of the mux inputs in developing your solution.

Your logic will produce a new position for the servo (a 7b value, representing the position of the front wheel and attached "head").

Your inputs are:

Input	**Represents**
loudest[2:0]	Which of the 8 microphones hears the loudest whistle code
currentplus6	1 if current position+6 degrees is louder than the microphone 0 at the current position; 0 otherwise
currentminus6	1 if the current position-6 degrees is louder than the microphone at 0 at the current position; 0 otherwise
current_position[6:0]	The current position
current_position_plus[6:0]	The current position plus 1 degree
current_position_minus[6:0]	The current position minus 1 degree

You may answer with text (this box) or a picture (next box) or both.

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Question 13

0 pts

Alternately, use this upload to answer the above logic design question.

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With loudness extraction per frequency and the logic above to orient the front wheel toward the source, the robotic dog and start moving toward the source of the whistle command.   This should make the sound louder.

Now that we can get the robot dog's attention, we would like to be able to give it more commands than just "come here". Using the T frequencies identified in question Question 9 let's think about forming a communication packet that can select a particular robot dog and send a command.

With T frequencies occurring at once, the "whistle" probably begins to sound more like a "bark".

Question 14

4 pts

Assume you want to work with a set of at most 256 robot dogs in audible range of the whistle, describe how you form a packet from the T frequencies identified.

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Question 15

3 pts

For your identified packet, how many distinct payload commands can be encoded?

Question 16

0 pts

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Question 17

0 pts

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We also equip the robot dogs with a speaker, pointed in the direction they are facing (position 0, orientation of front wheel). Robot dogs can use this to respond to commands. Assume they use the same packet format as developed above with a distinct subset of the command payloads for their responses.

Question 18

5 pts

How could a robot dog (all robot dogs) relay whistle packets to extend the communication range?

[hint: may want to exploit the ability to control the orientation of the speaker]

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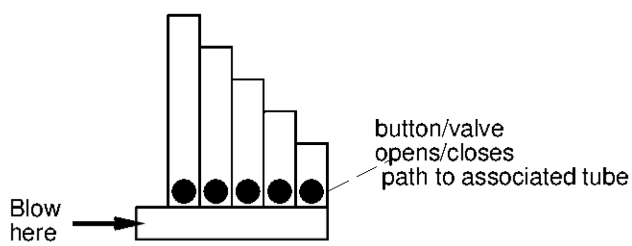
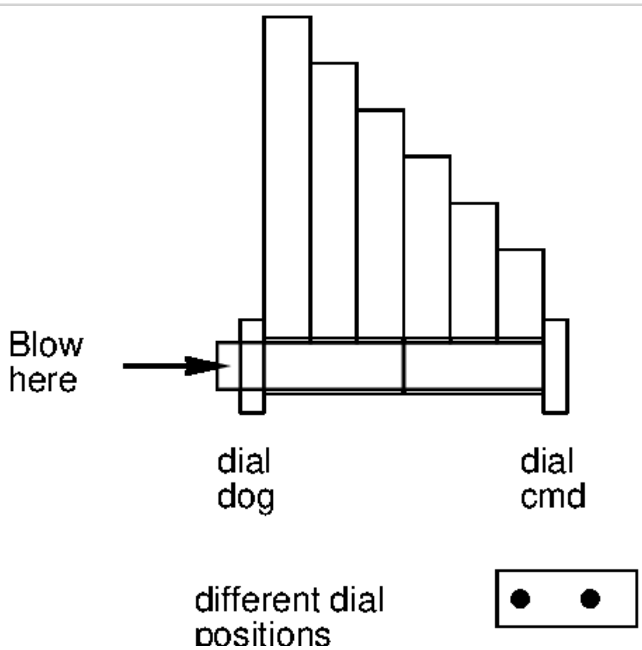
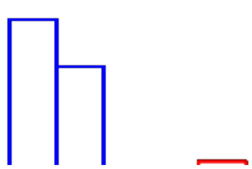
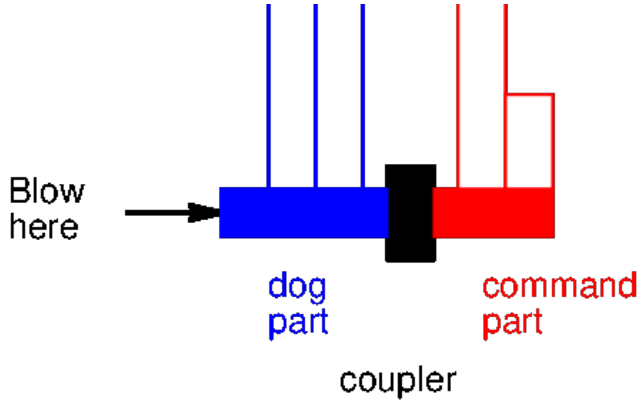
Question 19

4 pts

Consider the following choices for the command whistle that a human can use to send "whistle/bark" packets.

ID	Name	Diagram	Description
A	Tube per frequency		Each tone has its own tube with a button/plunger. Pressing the plunger controls whether or not the tube produces a tone or not. The user pushes the buttons and blows to get the frequency set for a packet.
B	Dial for dog, command		There are two dials. One select the dog, the second selects the command. Turning the dial selects which set of tubes are open or closed. Knob to turn is labelled by dog name or command

			name, respectively.
C	Smart phone app		The whistle is actually an app on a smart phone. Tones are produced by performing a frequency to time domain transformation. The user gets a scroll wheel to select the dog, then a scroll wheel to select the command, then the a button to press to trigger the "whistle/bark". The commands on the scroll wheel are ordered with the most frequently used commands at the from of the scroll wheel. Sending a second packet starts with the scroll wheels where they were last set, so there is no need to change a dog or command that is not changing.
			The whistle comes in two halves. One half is for the dog and the other for the command. The user

D	Per dog + command tube set		gets a kit of tube sets for each half. E.g. a dog tube has just the set of tubes where the tone is present. The user selects a dog half and a command half, connects them together, and blows the whistle.

Rank from most usable (1) to least usable (4).

A	[Choose]
B	[Choose]
C	[Choose]
D	[Choose]

Question 20

4 pts

Identify good and bad aspects of each interface.

You may need to put multiple things in a good or bad blank. Similarly, there may be no good or bad aspect of a design.

Interface	Good	Bad
A		
B		
C		
D		

Question 21

2 pts

Another smart phone app (either independently or part of the logic in the smart phone app option above), can convert whistle/bark packets back to logical dog and response payloads. Assuming each robot dog is programmed to acknowledge whistle/bark commands, how does the addition of this response interpreter change the user experience?

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Question 22

0 pts

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Question 23

3 pts

All this whistling and barking could get very noisy. How could we keep the basic design with less noise pollution for humans?

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Question 24

5 pts

For your solution above and keeping the frequency sample window at 25ms, what is the implication on processing power needed? The answer should be quantitative.

Describe your solution strategy and state your assumptions.

For simplicity of this problem (and the next), assume the time to read an analog sample can be made negligibly small.

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Question 25

5 pts

How could you support the new processing power requirement identified in the previous question?

[Hint: you may think about making changes to the hardware used for processing.]

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Question 26

0 pts

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So far, we've specifically considered only simultaneous tone sets.

Alternately, we could consider a sequence of tones. We might play a different tone set in each 25 ms window, and build the packet from a sequence of S such windows.

Assume we set the tone set size to 4 and want to support the same set of packets as previously developed for simultaneous tones (Questions 14--15).

Question 27

5 pts

How much longer does it take to send a command with the sequential scheme (give a ratio Tsequential/Tsimultaneous)

Question 28

5 pts

How much less processing power does the sequential version require? (ratio: multiplies-per-second-simultaneous/multiplies-per-second-sequential)

Question 29

0 pts

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Question 30

0 pts

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Question 31

1 pts

Assuming you implement the robot dog and the smart phone apps, there are parts of your design that are copyrightable.

- True
- False

Question 32

2 pts

Explain why or why not. (if true, identify what might be copyrightable; if false, detail why no component can be copyrighted.)

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Question 33

1 pts

Ignoring prior art issues, you can patent the description in the first box.

- True
- False

Question 34

2 pts

Why or why not?

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Question 35

1 pts

Ignoring prior art issues, if you built a prototype based on your answers to this quiz and demonstrated that it worked, you can patent the design?

- True
- False

Question 36

2 pts

Why or why not?

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Question 37

0 pts

[optional] Use this space to show work on problems above (since last show-your-work space).

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Question 38

1 pts

I complied with the University of Pennsylvania Code of Academic Integrity in completing this exam.

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(https://catalog.upenn.edu/pennbook/code-of-academic-integrity/)

including following the exam-specific regulations

https://www.seas.upenn.edu/~ese150/spring2021/final_details.pdf
(https://www.seas.upenn.edu/~ese150/spring2021/final_details.pdf)

- True
- False

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