Midterm 2 - DSC 40A, Winter 2024

## Instructions

- This is a 50 -minute exam consisting of 4 questions worth a total of 40 points.
- The only allowed resource is your hand-written reference notes.
- No calculators.
- Please write neatly and stay within the provided boxes.
- You may fill out the front page only until you are instructed to start.


## Statement of Academic Integrity

By submitting your exam, you are attesting to the following statement of academic integrity.
I will act with honesty and integrity during this exam.


PID: $\square$

Seat you are in: $\square$

Version - A

1. (6 points) Quarks is one of the smallest fundamental particles in physics. There are 6 types of quarks: up, down, top, bottom, strange, charm. Each one of the 6 quarks can be in two state: quark or antiquark.
a) Consider an experiment where we select n quarks uniformly at random. The result of the experiment is a description of the type and state of the quark selected. For example, if $n=3$, one possible result is:

- Selected quark 1 is a top quark.
- Selected quark 2 is a charm antiquark.
- Selected quark 3 is a top antiquark.

How many results are possible for this experiment with $n$ quarks?$6^{n}$$9^{n}$
$\bigcirc 12^{n}$$18^{n}$$36^{n}$None of the above.
b) A meson is formed by combining two quarks. In order to form a meson, the two quarks must satisfy the following rules:

- They must be in different state: one must be quark and the other one must be anti-quark
- The two quarks can be the same type: i.e. top quark and top antiquark can form a meson
- The order of quark and antiquark does matter.

Consider an experiment where we select n mesons uniformly at random. How many results are possible for this experiment?
$\bigcirc 2^{n}$
$\bigcirc 6^{n}$$12^{n}$$18^{n}$$36^{n}$None of the above.
2. (12 points) A special poker card deck contains the 52 standard card:
Heart: 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K, A
Diamond: $2,3,4,5,6,7,8,9,10$, J, Q, K, A
Club: 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K, A
Spade: 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K, A

Plus two wildcard: Red Joker and Black Joker. The total numbers of card in this card deck is 54.
a) (2 points) Ho many ways to select a 4 card hand from this card deck? (Note: order does not matter in a card hand.)
$\square$
b) (4 points) For this deck, how many 5 card hands are there that include a four-of-a-kind (four cards of the same value)? Show your work.

## Proof:

c) (6 points) In certain poker rules, a bomb is defined as either four-of-a-kind, or two wildcards (red joker and black joker). Suppose you randomly draw 4 card hand and you found a bomb in it, what is the probability that the bomb is four-of-a-kind? Show your work.

## Proof:

3. (16 points) Schrödinger's cat is a famous thought experiment in quantum mechanics proposed by physicist Erwin Schrödinger in 1935. The experiment is described below:
"Imagine there's a hypothetical cat in a closed box with a toxic radioactive element that might decay. If it decays, the cat dies; if it doesn't, the cat lives."

Please note that Schrödinger's Cat is a purely theoretical concept-a thought experiment. It has never been executed in the real world, and no cats have ever been harmed as a result of it.
a) (6 points) Suppose the cat has $90 \%$ of the chance to die if the decay happens. The cat also has $10 \%$ chance to die even if the decay does not happen. Suppose the decay happens with a $20 \%$ probability. After you open the box, you find the cat dead. What is the probability that the decay happened?

Proof:

Quantum superposition is a mind-bending and counter-intuitive concept in physics. In Schrödinger's cat scenario, when the box is closed, the cat can be both dead and alive simultaneously. However, once we open the box and observe, the superposition collapses, and the cat must be either dead or alive, not both.
b) (4 points) The Venn Diagram below depicts Schrödinger's cat scenario with the box closed. In this diagram, the black dotted line is the event of cat dead, the red dashed line denotes the event of cat being alive, and the shaded region is the event of decay.


Based on this Venn diagram, which of the following is true? Select all that applies:
Decay is independent of Cat DeadDecay is independent of Cat AliveCat Dead and Cat Alive are mutually exclusive.
$\square$ Cat Dead, Cat Alive, and Decay form a partition of the sample space.None of Above.
c) (6 points) Given the following probabilities:

- $\mathrm{P}($ Cat Dead $\cup$ Decay $)=\frac{4}{5}$
- $\mathrm{P}($ Cat Alive $\cup$ Decay $)=\frac{1}{2}$
- $\mathrm{P}($ Cat Alive $\cup$ Cat Dead $)=1$
- $P($ Decay $)=\frac{1}{5}$

Using the Venn diagram in part b), calculate the probability for Schrodinger's cat to be in superposition state (i.e. both dead and alive):

## Proof:

4. ( 6 pt ) The standard acceleration of gravity $g$ is a universal constant of nature. That means $g=9.80665$ across the entire universe. It is also known that:

$$
\begin{equation*}
G=m \times g \tag{1}
\end{equation*}
$$

Where $G$ is the weight of an object and $m$ is the mass of an object. Issac is interested in measuring $g$. He prepared a dumbbell with mass 10 in his garage and measured the weight of it 3 times. The measured weight is $102,98,100$
a) (1pt) Calculate the mean value of $g$ Issac measured.

b) (2pt) After his measurement, an alien from the Frequentist Galaxy visited Issac's garage. Alien from Frequentist Galaxy could only understand frequentist statistics. Explain to the alien why Issac's measurement deviates from $g=9.80665$ (Hint: verbal explanation is enough, no equation is needed):

## Explanation:

c) (2pt) After the first alien left, another alien from the Bayesian galaxy arrived. This alien told Issac: "I think g could take any value: it could be 1 , could be 10 , could be $100 . "$. Using the Bayes equation and Issac's measurement, convince the alien that g should be close to 10 .

## Explanation:

d) (1pt) Which explanation do you prefer? (Note: both answers are correct, enjoy your one free point).
Bayesian

