
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.
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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.

Name:

PID:

Seat you are in:

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
- 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?

- 2^n
- 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.)

- 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.”

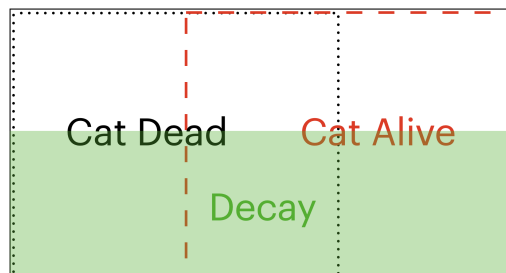
Please note that Schrödinger’s Cat is a purely theoretical concept—a thought experiment. It has never been executed in the real world, and no cats have ever been harmed as a result of it.

- 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 Dead
- Decay is independent of Cat Alive
- Cat Dead and Cat Alive are mutually exclusive.
- Cat Dead, Cat Alive, and Decay form a partition of the sample space.
- None of Above.

c) (6 points) Given the following probabilities:

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

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:

