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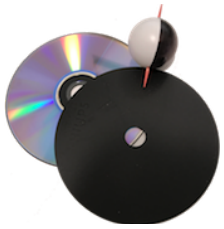
Measurements in the Quantum World

Learning Objectives

- Learn how to describe a (classical) spinning coin with a probabilistic model.
- Build a probabilistic model for a (classical) spinning “spherical coin”.
- Understand the difference between random and unpredictable processes.
- Discover the fundamental difference between quantum and classical measurements.

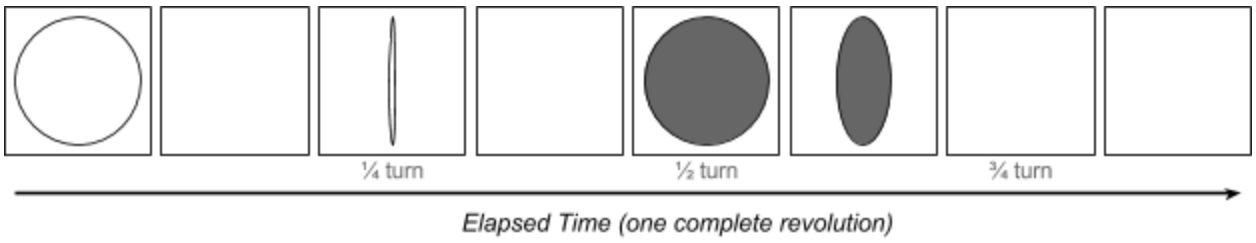
Equipment

- 1 “classical coin” + 1 “spherical coin” per group.
- Laptop / tablet / phone with web browser.

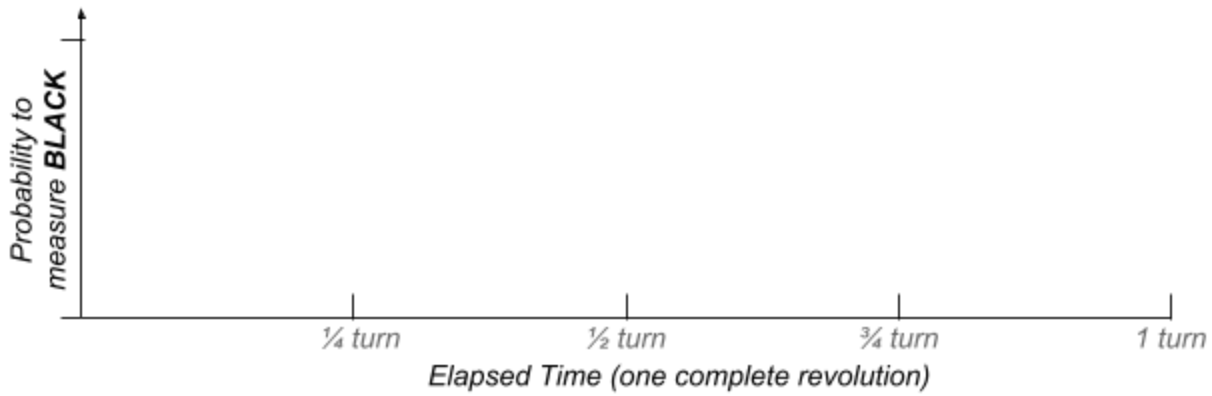


Classical Coin

1. Work in pairs, with one person playing the role of the “universe” and the other playing the role of the “observer”.
    a. The “universe” slowly spins a classical coin at a constant rate. Keep going, no matter what the observer is doing.
    b. The “observer” faces the the coin with their eyes closed then, at a random time, opens their eyes and makes a quick sketch of what they see. Repeat this a few times to make several quick sketches.
2. Work together to complete the sketches below, showing snapshots during one complete revolution of the classical coin.

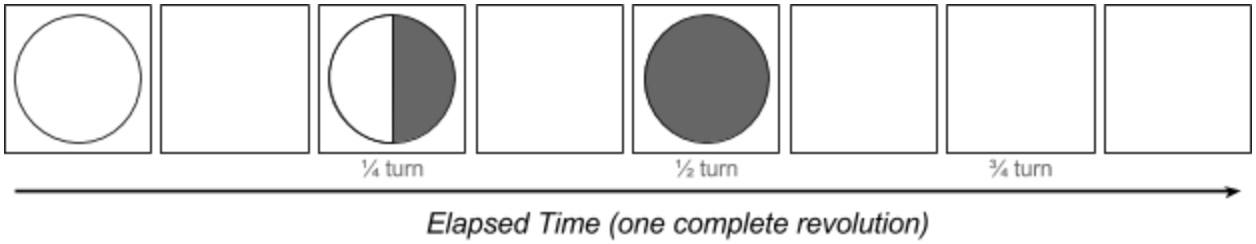


3. What is the probability that the observer “measures” (sees) a black face in each snapshot above? Fill in the graph below showing this probability as a function of time.

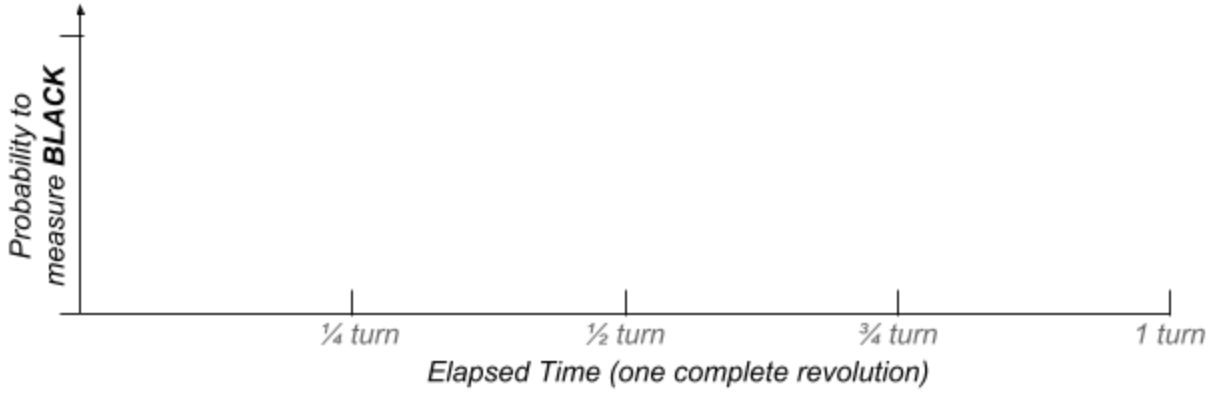


Spherical Coin

1. Swap “universe” and “observer” roles and repeat the steps above to add the missing snapshots below.



2. Since you can generally see both “sides” of the sphere at once, we need a new definition of “measurement”: imagine throwing a dart randomly towards the sphere. The resulting measurement is determined by whether the dart hits a WHITE or BLACK point (assume that no darts miss the sphere completely).
3. Using this definition, what is the probability that the observer “measures” BLACK in each snapshot above? Fill in the graph below showing this probability as a function of time. A rough sketch is ok. No calculations are necessary.



4. Is the outcome of a measurement random? Is it predictable?
5. Discuss with your partner how the spherical coin relates to something you can usually see in the night sky.

Classical vs Quantum Coin

1. Visit https://dkirkby.github.io/quantum-coin/ and click the “START” button.
2. How does the graph relate to your Classical Coin graph?
3. Click the “MEASURE” button a few times. What do the green lines represent? Does making a measurement affect how the coin spins?
4. Click “RESET” then select “Quantum” instead of “Classical”, then click “START”.
5. How does the graph relate to your Spherical Coin graph?
6. Click the “MEASURE” button a few times. Something weird happens: describe it.
7. What do the green dots represent?
8. Is it possible to keep the quantum coin in the same state with repeated measurements?
9. Visit https://dkirkby.github.io/quantum-coin/about.html and discuss with your instructor.