Physics 008: The Quantum World Around Us
Spring 2006
Midterm Exam
Thursday, March 16, 2006 **Name:**

This is a closed book exam. You have 75 minutes. Good luck.

Georgetown University is subject to an Honor System. Please remember your commitment to academic integrity while taking this examination.

1. (30 points) Give **brief** answers to each of the following questions. *(3 points each.)*

   (a) When electrical current flows through a current loop, the current loop acts like a magnet. Describe how we use the right-hand-rule to determine the direction of the north pole of this magnet.

   (b) Nuclear magnetic resonance is widely used in chemistry due to a phenomenon known as the chemical shift. Describe what the chemical shift is and why it is useful to chemistry.

   (c) In the came of craps, one gets extra money for betting on a "hard-way" even number, such as a 4, 6, 8, or 10, which is rolled with two matching numbers on the dice. What is the probability to roll such a hard-way pair (totaling 4, 6, 8, or 10)?

   (d) Describe under what circumstances *no atoms* exit a Stern-Gerlach analyzer loop when one of the branches is blocked.

(e) If you shine blue light onto an oil slick, which involves a thin layer of oil sitting on the surface of water, what will you see?

(f) A two slit experiment shows a pattern of bright and dark bars on a screen as seen in picture 1. Something is changed in the experiment to result in picture 2. Explain what might have changed and how it changed for the experiment to have its result modified from picture 1 to picture 2.

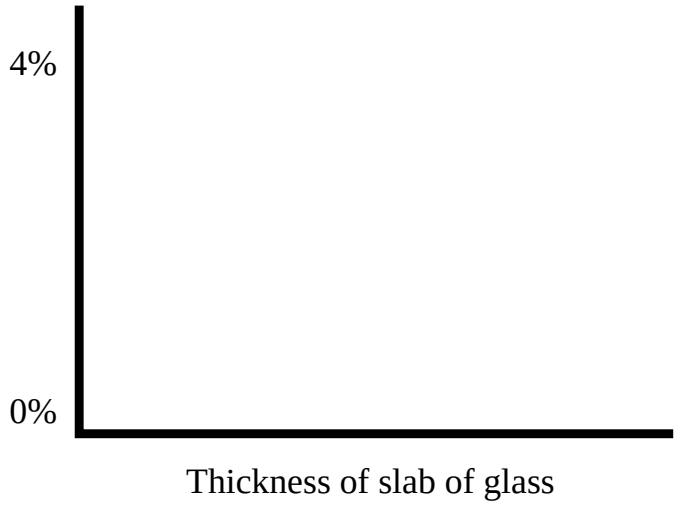
Picture 1

Picture 2

(g) Explain what the word resonance means in a nuclear magnetic resonance experiment.

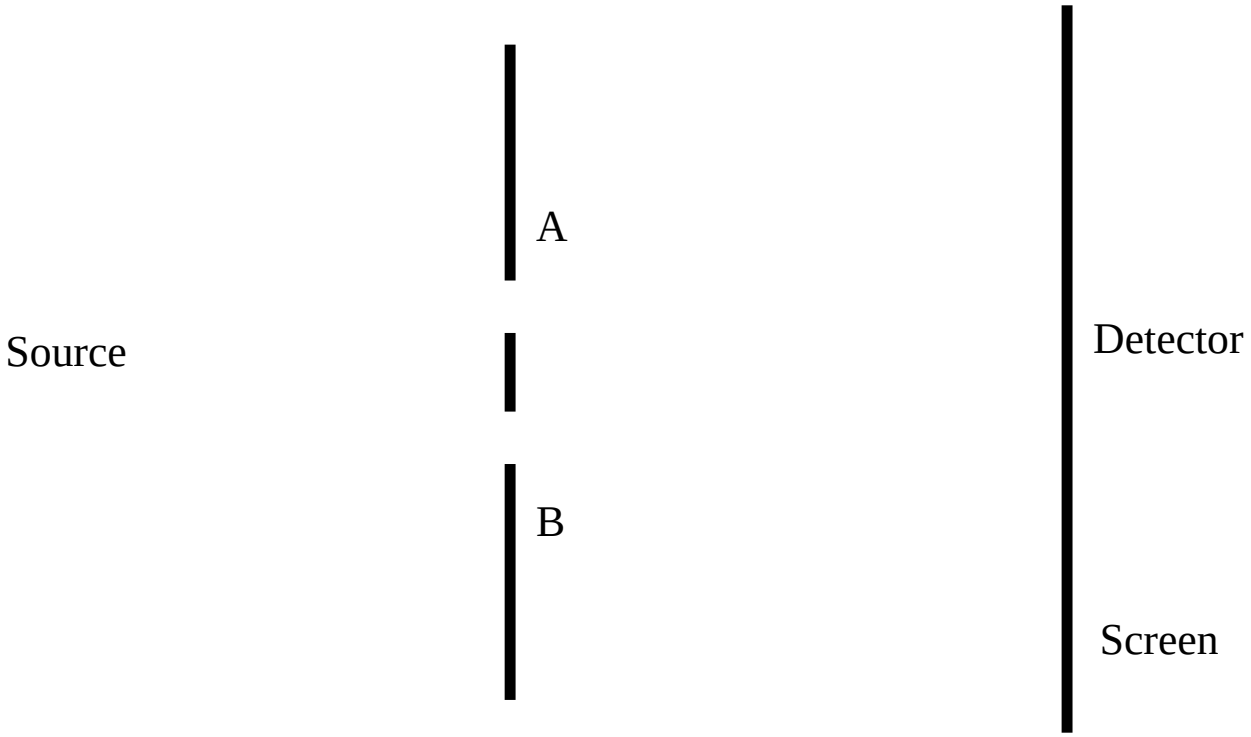
(h) Define what is meant by the effective magnetic needle associated with a current loop.

(i) When we examined partial reflection off a thin piece of glass, we found that between 0% and 4% of the light incident on the glass was reflected. Given that the stopwatch for blue light rotates about twice as fast as the stopwatch for red light, sketch how the probability for reflection varies with the thickness of the slab for red light and blue light (on the same graph). Be sure to label your curves clearly and explain why you drew what you drew.



(j) Name and describe an experiment that shows that light displays particle properties.

2. (20 points) Consider the following two slit experiment:



When either slit is blocked, 4% of the photons leaving the source will arrive at a detector placed anywhere along the screen.

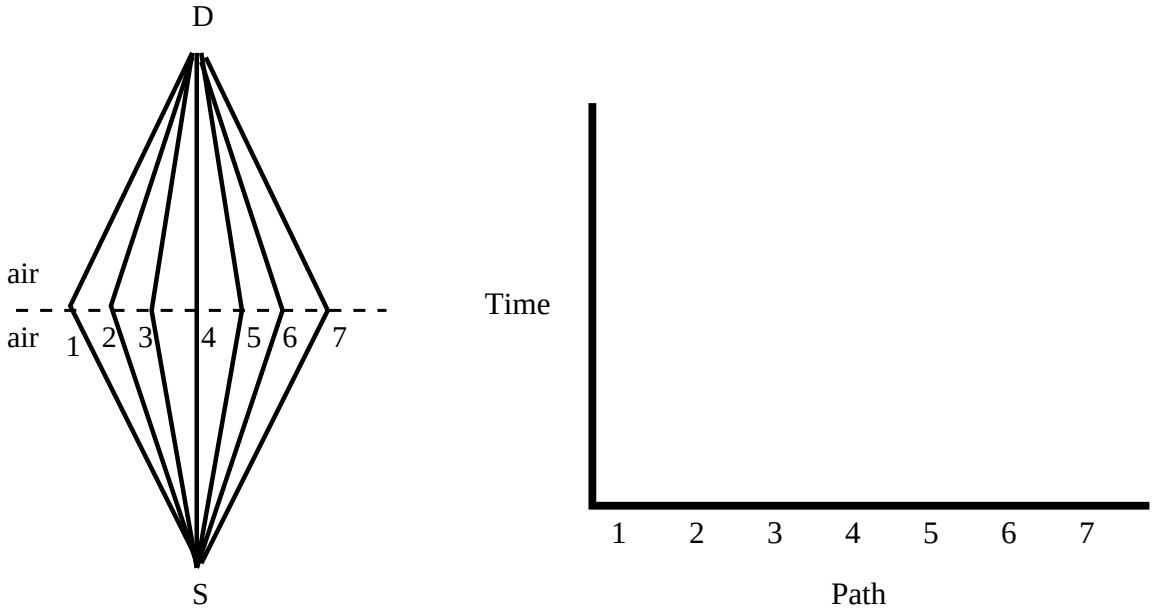
(a) (5 points) Assuming the photons are unwatched, what is the range of possible probabilities for detection in the detector when both slits are open (show your work to receive any credit).

(b) (5 points) A detector A^* is added at the top slit. It is 100% efficient. What is the range of probabilities for detection in the detector now? (Show work to receive credit.)

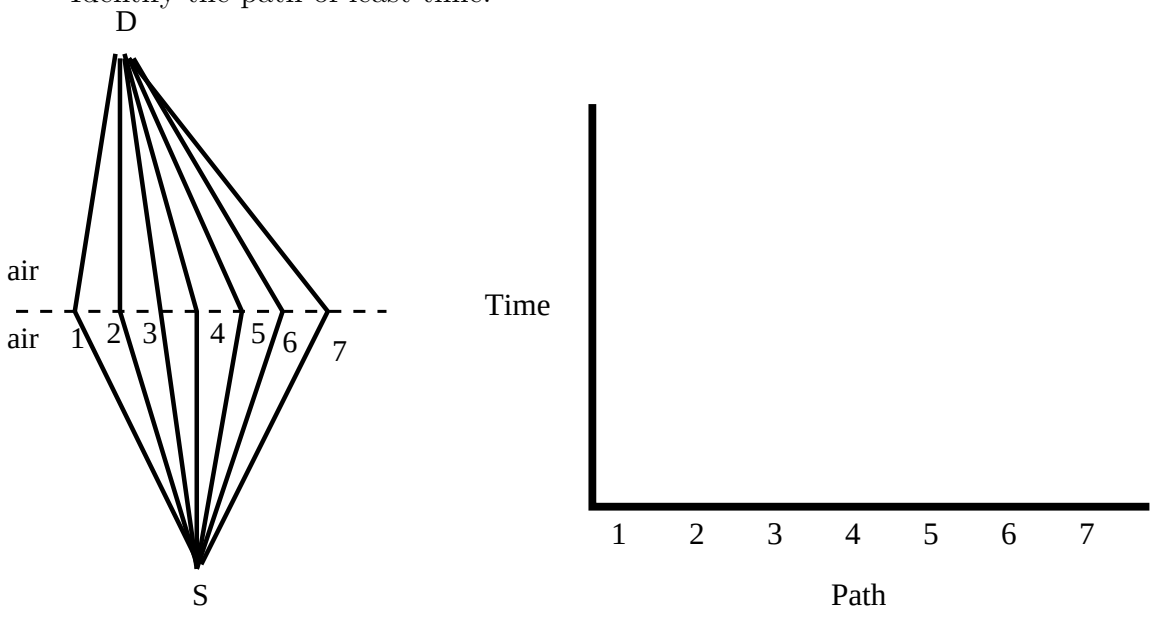
(c) (5 points) The detector A^* breaks down, and only works 36% of the time. Determine the events for detection in the detector at the screen, and the alternative ways that the photon can be detected for each event.

(d) (5 points) Find the range of probabilities for detection when the detector A^* works only 36% of the time. (Show work to receive any credit.)

3. (20 points) A source of single-color light and a detector are set up as shown in the figures below. We consider seven different possible paths that go from the source to the detector.

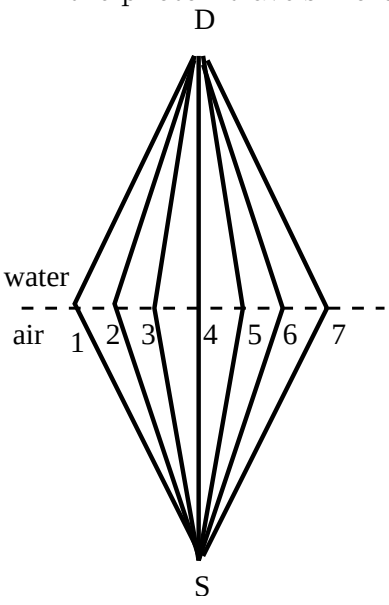


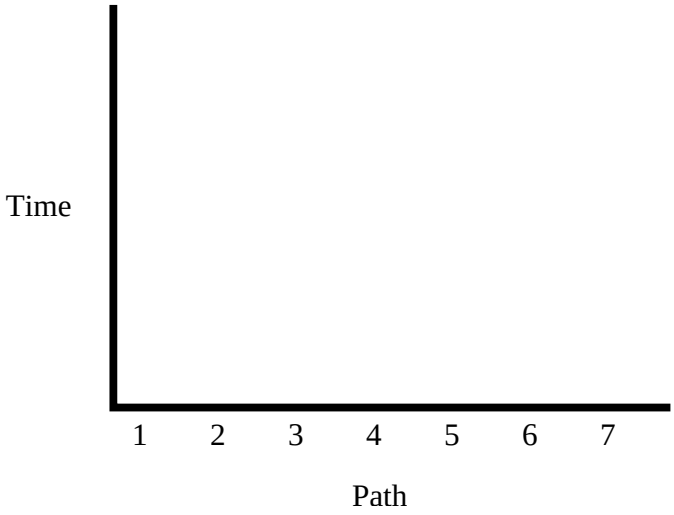
a. (5 points) The photon travels through air only. Plot how the time for the photon to travel from the source to the detector varies for each path given in the above figure. Identify the path of least time.



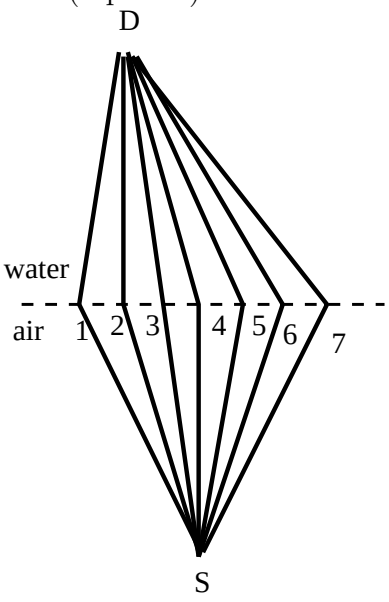
b. (5 points) Repeat now for the above arrangement of source and detector.

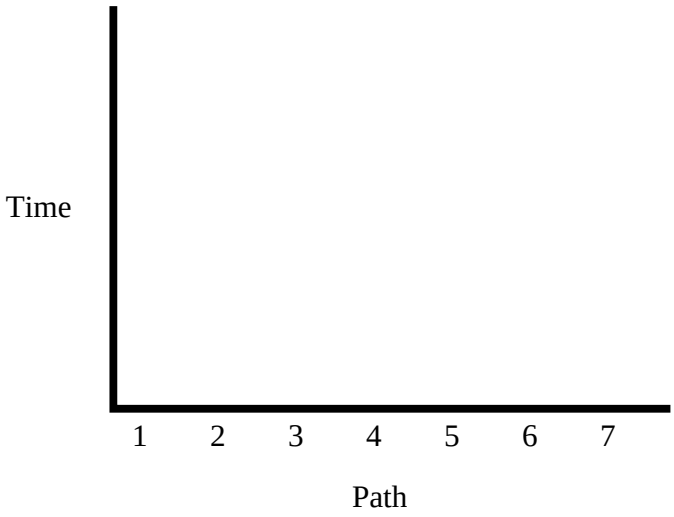
Now the upper half of the space has the air replaced by water. Note that in water, the photon travels more slowly than in air.





c. (5 points) Plot the time versus path again. Identify the path of least time.





d. (5 points) Plot the time versus path again. Identify the path of least time.

4. (30 points) *Short essay.* The Stern-Gerlach experiment was designed to separate (or measure) the projection of a set of current loops on the axis of increasing magnetic field. Explain how a Stern-Gerlach experiment is actually set up, and what the expected out come is if we inject a beam of randomly oriented atoms, and we treat them as classical objects. When an actual experiment is performed on silver atoms, we need to examine the quantum-mechanical experiment. Describe what the results of the quantum-experiment will be as well. (The best essays will include figures in their discussions and will describe results under the most general conditions; please try to be a clear and specific in the way you word the answer to your essay.)

(Use this sheet as scratch paper. If you want something on this page to be graded, be sure it is clearly marked as such.)