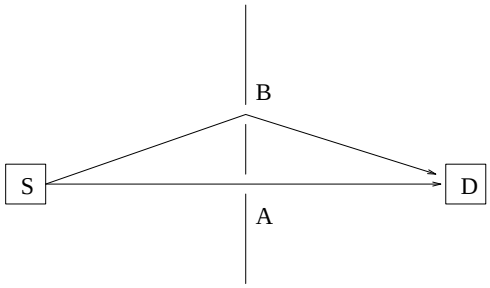
Physics 008: The Quantum World Around Us
Spring 2007
Homework Assignment #5
Due Thursday 2/22/06 **Name:**

1. Consider the two-slit experiment involving monochromatic light. If either one of the holes is blocked, 1% of the photons leaving the source S are detected by the photomultiplier at D.



In each of the following cases, the holes at A and B are both open.

(a) Suppose the experiment is performed without detectors at A and B (Expt. 3 in class). What are the event(s) that involve detecting a photon at D?

For each event listed above, how many alternative ways can the event happen? If there are multiple ways, list them.

Using the quantum rules for determining the probability of events, find the probability that a photon leaving S will arrive at D. Note that your answer may depend on the geometry of the experiment (*e.g.*, the separation between A and B). What are the minimum and maximum possible probabilities?

Make a graph showing the probability of detecting a photon at D as a function of the separation between A and B. (Be sure to label the axes on your graph.)

(b) Suppose detectors A^* and B^* are placed at A and B to determine which hole a photon passes through (Expt. 4 in class). What are the event(s) that involve detecting a photon at D?

For each event listed above, how many alternative ways can the event happen? If there are multiple ways, list them.

Using the quantum rules for determining the probability of events, find the probability that a photon leaving S will arrive at D. Note that your answer may depend on the geometry of the experiment (*e.g.*, the separation between A and B). What are the minimum and maximum possible probabilities?

Plot the probability of detecting a photon at D as a function of the separation between A and B.

(c) Suppose the detectors A^* and B^* placed at A and B are **not perfect**. Sometimes a photon can pass through hole A without triggering the detector at A, and sometimes a photon can pass through hole B without triggering the detector at B. (The detector D still detects all photons that arrive there.) What are the event(s) that involve detecting a photon at D?

For each event listed above, how many alternative ways can the event happen? If there are multiple ways, list them.

Determine the amplitude and probability of each event listed above. Assume the detectors at A and B are 64% effective. That is, for every 100 photons detected at D, 64 trigger clicks at either A or B, while 36 do not. (Hint: This means for example that the probability of an event involving clicks at both A and D is 64% of the value it would be if all the detectors were perfect. The amplitude of an event involving detection at both A and D therefore involves an additional shrink of $\sqrt{0.64} = 0.8$ compared to the case of perfect detectors.)

What is the total probability that a photon leaving S will be detected at D? Again, your answer may depend on the geometry of the experiment. What are the minimum and maximum possible probabilities?

Plot the probability of detecting a photon at D as a function of the separation between A and B.

2. *Short Essay*: **In your own words**, explain how the mirage mentioned in Chapter 2 of Feynman's *QED* forms. You should construct your explanation in such a way that *your fellow students in this course would be able to understand it.*

   Be sure to include all of the following mandatory elements in your discussion:

   - Describe what the mirage is, and under what conditions it forms.
   - Use a quantum mechanical description of light to show how it is possible to see the sky when you look down at the road surface. This requires thinking about different paths photons can take from the sky to your eyes, and comparing arrows for the paths.
   - Use sketches and graphs to make your arguments easier to understand.