1. Solutions

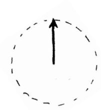
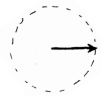
(1) In the EPRB experiment -
  (a) It is not possible to send a message using such an experiment because neither Alice nor Bob can pre-determine the results of their measurements. If they could then they would know with probability 1 that the other observer has the opposite state. For instance if Alice could ensure that her result is $m_z = +m_B$ then she would know that Bob measures $m_z = -m_B$. By coding the message in a series of $+m_B$'s and $-m_B$'s (like 0's and1's), Alice could send a message super-luminally. However, this is not what happens. There is no way to pre-determine the outcome and send a super-luminal message.
  (b) Even if the local realist view was correct, it would not be possible to send a message using this technique for the same reason: the observers cannot force an outcome for the measurement.

(2) Mr. Parker is a local realist (reasonably enough!). Endowing individual particles with states (in this case $m_x = +m_B$ for one and $m_x = -m_B$ for the other) is clearly consistent with the result that the atoms leave the + exit 1/2 the time and leave the - exit 1/2 the time (Stern-Gerlachs all in the z-orientation). However, since either outcome occurs with probability 1/2, the possibility that the particles both exit on the + path is $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$, which is not observed.

(3) The orientation of the analyzers is different so we have to consider the cases ab, ac, bc and the settings in reverse order. Suppose Alice has a setting of a and measures $m_a = -m_B$, then with probability 1 Bob has a particle in the $m_a = +m_B$ state. If Bob chooses either the c or b setting then, by the chart, the probability is 1/4 for a $+m_B$ outcome. Since all axes are separated by 120 degrees this holds for all three settings on Alice's analyzer. Now if Alice has a setting of a and measures $+m_B$, then with probability 1 Bob has a particle in the $-m_B$ state. Now we have the "inverse" problem of what is posed in the chart: What is the probability that a - state will exit a - exit on the tilted analyzer? (Note that this is not asking, "What is the probability that a + state will exit a - exit on the tilted analyzer?" which we could simply answer with the chart by computing $1 - P(\theta)$.) In this case, the results are the same as the pervious "$+m_B$" case. So if Bob chooses either the c or b setting then Bob again observes $-m_B$ the probability is 1/4 for a outcome. Since every case ab, ca, etc. has probability 1/4 then the total probability for different color flashes when the settings are different is 1/4.

(4) For one instruction set, the probability for the different flashes is given in the table of page 45. So the total probability of different flashes is the probability for the instruction set times this different flashes probability. So I find

$$P = 1 \times \frac{1}{2} + \frac{5}{9} \times \frac{1}{4} + \frac{5}{9} \times \frac{1}{8} + \frac{5}{9} \times \frac{1}{8} = \frac{7}{9}.$$

(5) 8.1 So we're adding , , and . The easiest thing to do is to add the first two to find an arrow pointed "northeast" with length $\sqrt{2} \cdot 5$ inches, as determined from the Pythagorean theorem. Now this arrow and the final one point in the same direction so we can just add their lengths to find $(\sqrt{2}+1)5 = 12.07$ inches

(6) Blocking the "-" exit means the final state is $m_z = +m_B$. So if a or b are blocked, since these states are $m_x = \pm m_B$, the probability of an atom exiting successfully is 1/4 ($P = 1/2$ for transitioning from A to B and $P = 1/2$ for transitioning from B to C, in the notation we used in class), just as it was before with the "+" exit blocked. If both routes are open then the atom will exit the apparatus with probability 1.

(7) (a) The first two interferometers do not affect the state. So the percentage exiting is 50 %, due to the "3a" path being blocked.
(b) Same as part a.
(c) The first interferometer does not affect the state so the atom is still in the $m_z = +m_B$ state entering the second interferometer. So all the atoms are stopped by the "2a" block, 0%.
(d) As in part c but now the percentage is 100% since all the atoms are in the $m_z = +m_B$ state.
(e) Similar to parts a and b, 50%.
(f) The only route through the second interferometer is the state $m_z = -m_B$, but the initial state is $m_z = +m_B$ so 0 % make it through.
(g) Since the same state ($m_x = -m_B$) is blocked in the first and last interferometers, and since the middle one does not affect the state, only the "1b" blockage stops atoms; 50 % make it through.
(h) Since the $m_x = -m_B$ state is blocked in the first interferometer and the $m_x = +m_B$ state is blocked in the third interferometer, no atoms, 0 %, make it through. (i) Now the state is altered by the second interferometer so the state is initially $m_x = +m_B$ (1/2 blocked), then $m_z = -m_B$ (1/2 blocked), then finally $m_x = -m_B$ (1/2 blocked). Hence, $(1/2)^3$ =12.5 % > 0 (!) make it through.

(8) It matters whether the photon was deflected. For instance, the probability of the atom to exit "-" in figure D is 0 since the state remains $m_z = +m_B$. If the photon is deflected as in figure B, the probability of the atom to exit "-" is 1/2, since we now know that the state was $m_x = +m_B$ in the interferometer.

(9) (a) We need a sum of amplitudes that, when both paths have non-zero amplitudes (1/2 as on page 90), gives $\cos(\theta/2)$. In Mr. Parker's scheme the amplitudes of $\pm 1/2$ could only give 0 or 1.
(b) From Pythagorus, the amplitudes in this scheme would be effectively 90 degrees apart so the amplitude $A_{a,b}$ would be $\sqrt{2(1/4)} = 1/\sqrt{2}$ instead of $\cos^2(\theta/2)$.

The problem with Mr. Parker's schemes is the loss of "direction" in the amplitudes. These terms can determine the outcome, as in experiment 11.B.3 on page 90.

(10) Path A to B occurs 1/2 the time so the amplitude is the square root of this $\sqrt{1/2}$. A to C occurs 1/2 the time so the amplitude has magnitude $\sqrt{2}/2$. A to D doesn't occur; these are EPR entangled pairs so the amplitude has length 0.

(11) Single photon interference

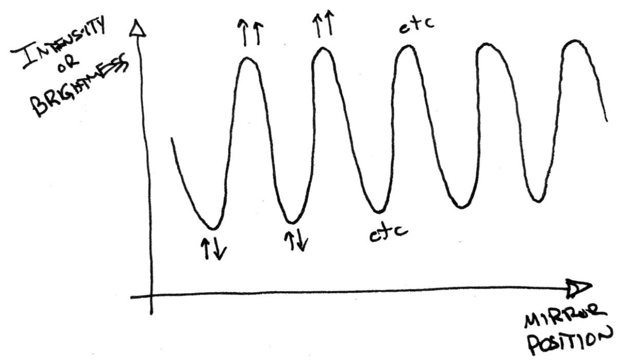
(a) Since there are 10 mm in 1 cm the amplitude rotates $10 \cdot 1910 = 19,100$ times in 1 cm. (Or it rotates 68,760,000°.)

(b) In one arm of the interferometer the mirror moves. As it does so the photon's path changes by twice the amount since the light travels to and from the mirror. So as the mirror moves 1.18 μm the amplitude rotates by

$$2 \cdot 1.18 \times 10^{-6}\ \mathrm{m} \ \cdot \frac{1910}{1 \times 10^{-3}\ \mathrm{m}} \simeq 4.5.$$

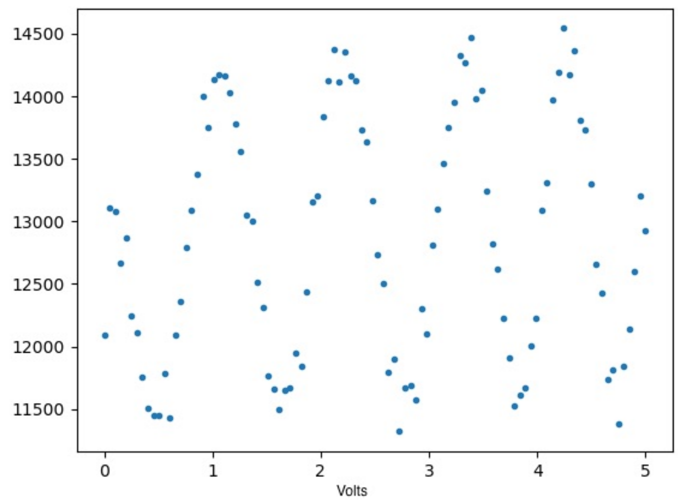
So if we start with a dark band then we would 4 pass by and we would end on a bright fringe.

(c) Here's my sketch



The starting point is arbitrary. The amplitudes must be parallel for interference maxima and antiparallel for minima but the overall orientation doesn't matter. (Only relative phase is physical.)

(d) Because we see an interference pattern in the data,



every *single individual* photon in the experiment interfered with itself. Notice that this is just what we expect. We see about 4.5 fringes.

(e) When one path was blocked the photons could travel on only one path and so they could not interfere.