Spacetime and the Quantum World Questions

Fall 2010

1. Clicker Questions from Class:

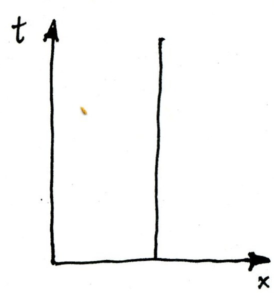
(1) While the cameras at the Olympics are moving, do they represent an inertial reference frame?
  (a) YES
  (b) NO
(2) An inertial reference frame is
  (a) characterized by uniform motion.
  (b) associated with any observer.
  (c) any reference frame used to describe events.
  (d) a set of meter sticks and clocks on Earth.
(3) Two, identical (excepting paint schemes), elastic balls collide. Before the collision the pink ball on the right moves to the left at 7 ms^{-1}. The white ball on the left is stationary. In what reference frame do you already know what happens after the collision?
  (a) Moving right at 7 ms^{-1}
  (b) Moving so that the pink ball is stationary
  (c) Moving left at 3.5 ms^{-1}
  (d) Moving left at 5 ms^{-1}
  (e) Moving right at 5 ms^{-1}
(4) In the original reference frame, what happens after the collision?
  (a) The pink ball moves to the right at 7 ms^{-1} while the white ball is stationary.
  (b) Both balls move to the left at 3.5 ms^{-1}.
  (c) The balls move away from each other at 7 ms^{-1}.
  (d) The pink ball is at rest and the white ball moves to the left at 7 ms^{-1}.
  (e) The balls move away from each other at 3.5 ms^{-1}.
(5) Two identical, sticky objects collide. What happens if the one on the left, moving at 10 ms^{-1}, collides with the stationary one on the right?
  (a) Both move at 10 ms^{-1} to the right
  (b) Both are at rest
  (c) Both move at 5 ms^{-1} to the right
  (d) They stop because they stick together
  (e) There is not enough information to answer this question.
(6) A "small" ball collides with a "big" ball. What happens if the big ball, on the right, moves to the left at $v = -10ms^{-1}$ and collides with the stationary small ball? The final velocities in this frame of reference are
  (a) small: - 10 ms^{-1}, big: 0 ms^{-1}
  (b) small: - 15 ms^{-1}, big: - 5 ms^{-1}
  (c) small: - 10 ms^{-1}, big: - 10 ms^{-1}
  (d) small: - 20 ms^{-1}, big: 0 ms^{-1}
  (e) small: - 20 ms^{-1}, big: - 10 ms^{-1}
(7) A "small" ball, on the left, collides with a "big" ball on the right. What happens if the two balls approach each other at the same speed s? The final velocities in this frame of reference are
  (a) small: $-4s$ ms^{-1}, big: $-s$ ms^{-1}
  (b) small: $-2s$ ms^{-1}, big: $-2s$ ms^{-1}

(c) small: $-3s$ ms^{-1}, big: $-s$ ms^{-1}
(d) small: $-2s$ ms^{-1}, big: $-s$ ms^{-1}
(e) small: $-s$ ms^{-1}, big: s ms^{-1}

(8) Two volcanoes, Mt. Rainier and Mt. Hood, are 500 km apart in their rest frame. Suppose that each erupts in a burst of light. An observer in a lab halfway between the two volcanoes receives the light from the two blasts at the same time. The observer's assistant is at the base of Mt. Rainier. The above objects (mountains, observer, and assistant) are at rest with respect to each other. According to the assistant does the eruption at Mt. Rainier *occur* before, at the same time, or after the eruption at Mt. Hood?
(a) before
(b) at the same time
(c) after

(9) Two whales, Alice and Bob, look for food between two pods P and Q. Alice and Bob are instructed to re-join the pod that signals first, unless both signal at the same time, in which case pod P has priority. Alice passes Bob, who is floating mid-way between the pods. She is heading to pod Q. A little while later Bob receives signals from both pods at the same time so Bob heads to P. Where does Alice go to?
(a) P since she also hears the signals at the same time.
(b) Q since she receives Q's call first.
(c) P since she receives P's call first.
(d) Q since Q emits the signal first.
(e) P since pod P emits the signal first.

(10) Viewed in an inertial reference frame, rolling stone merrily carries along at $+7$ ms^{-1}. What does its spacetime diagram look like?



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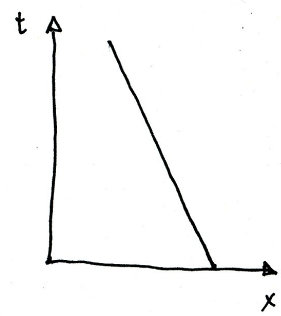

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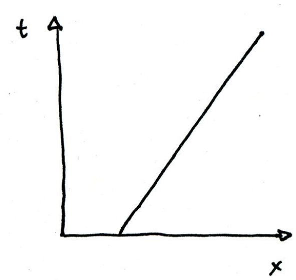

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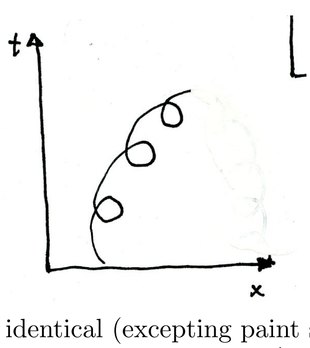
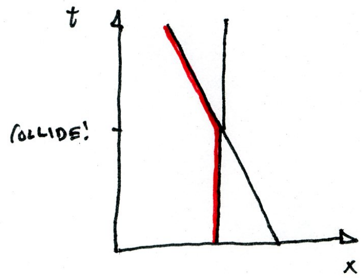


(d)

(11) Two, identical (excepting paint schemes), elastic balls collide. Before the collision the red ball (on the left) moves $+\ 7$ ms^{-1}. The black ball on the right is stationary. As you know, after the collision, the red ball is at rest and the black ball moves away at $+7$ ms^{-1}. What does a spacetime diagram of this look like?



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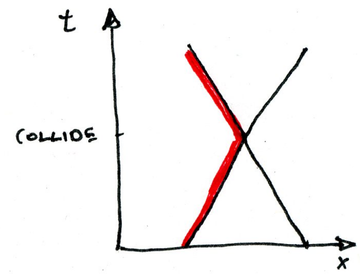

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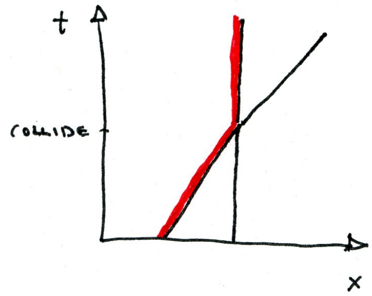

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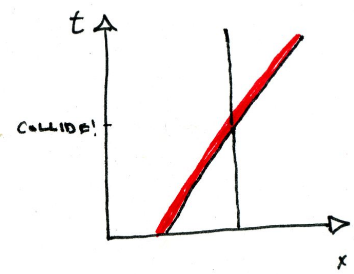

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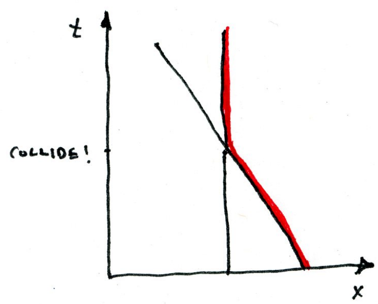


(e)

(12) At a particular time Mars is 360,000,000 km ($= 3.6 \times 10^{11}$ m) away from Earth. How long does it take for light to reach Mars from Earth? Use $c = 3 \times 10^8$ m/s.
   (a) 20 sec
   (b) 12 min
   (c) 1.2 sec
   (d) 120 min
   (e) 20 min

(13) At noon the President of Transylvania receives a message from an agent who is observing a secret base on Mars, "The missile targeting Castle Bran is set to fire at 12:15 PM. " Fortunately some days before, a Transylvania Special Operations team set explosive charges on the launch pad of the missile. Immediately after receiving the message, the President presses the button to activate the charges, thus sending a signal to Mars. Is the missile destroyed before it launches?
   (a) No
   (b) Yes
   (c) Who cares? Since Castle Bran is Dracula's Castle it will not be destroyed anyway!

(14) Two volcanoes, Mt. Rainier (on the left) and Mt. Hood (on the right), are 500 km apart in their rest frame. Suppose that each erupts in a burst of light. An observer in a lab halfway between the two volcanoes receives the light from the two blasts at the same time. The observer's

assistant is at the base of Mt. Rainier. The above objects (mountains, observer, and assistant) are at rest with respect to each other. A spacecraft flying by at 80 % of the speed of light and directed from Rainier to Hood is directly over Mt. Ranier when it erupts. According to an observer on the spacecraft does the eruption at Mt. Rainier occur before, at the same time, or after the eruption at Mt. Hood?
(a) before
(b) at the same time
(c) after
(d) the answer depends on unstated assumptions
Assume the mountains and observers are all on a single line. You can also neglect any non-inertial effects due to being on the surface of the Earth.

(15) The red line in the spectrum of hydrogen is at about
(a) 660 nm
(b) Wait, there is no red line!
(c) 450 nm
(d) 500 nm

(16) I see the line, dark this time, in the Sun's spectrum. This is because
(a) the sun has no hydrogen so no light is emitted at this wavelength
(b) the sun is not hot enough to emit light at this wavelength
(c) light at this wavelength is absorbed (by hydrogen) before the sunlight arrives on earth
(d) the light we see travels through glass so this wavelength is filtered out

(17) To find the redshift, $z = K - 1 = (\lambda_o - \lambda_e)/\lambda_e$, for this galaxy we need to find the H_α line. It is at approximately
(a) 610 nm
(b) 690 nm
(c) 920 nm
(d) 530 nm
(e) 570 nm

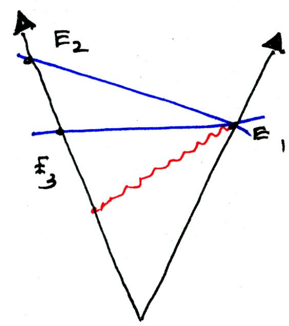
(18) Symmetry of time dilation ?!? Sasha's moving clock runs slowly in Anna's frame. By special relativity, since there is nothing special about either frame, Anna's clock must run slowly in Sasha's frame.
(a) Right. So it must be that this paradox shows a flaw in special relativity.
(b) Sure. These accounts are completely consistent since Sasha is moving.
(c) Yup. These accounts are completely consistent since the observers refer to different simultaneous events.
(d) No way. This account is wrong, only *the moving* clock runs slowly.

(19) An observer's world line tilts over by an angle towards the diagonal as the relative speed approaches c. in just two space-time dimensions (t and x) the *line* of simultaneity rises up by the same angle. For the light, traveling at c what is the appropriate description?
(a) all events in space-time take place in one place at one time
(b) all events on the light ray are simultaneous.
(c) most events in the space-time are inaccessible
(d) (b) and (c)

(20) On January 1st, Alice's birthday, Alice heads away from Bob at $v = 4/5c$ in the positive x direction ($K = 3$ and $\gamma = 5/3$). Bob calculates that he needs to send a "Happy Birthday!" message on February 11 (or 1/5 of a year) so that it arrives on the following January 1st, according to Bob's clocks. When does the message arrive, according to Alice's clocks?
(a) After one year, on January 1st.

(b) After 5/3 years or about August 1st of the following year, since $t = \gamma t'$ so $5/3 = 1 \times 5/3$
(c) After 3/5 of a year or about July 6, since $t = \gamma t'$ so $1 = t' \times 5/3$, thus $t' = 3/5$.
(d) After 3/5 of a year or about July 6, since $T' = KT$ so $T' = 3 \times 1/5$.
(e) After 3 years on January 1, since $T' = KT$ so $T' = 3 \times 1$.

(21) What does the space-time diagram of the history look like from Bob's frame? Event E_1 is the event of the arrival of Bob's "Happy Birthday" message. Event E_2 is simultaneous with E_1 in Bob's frame. Event E_3 is simultaneous with E_1 in Alice's frame.



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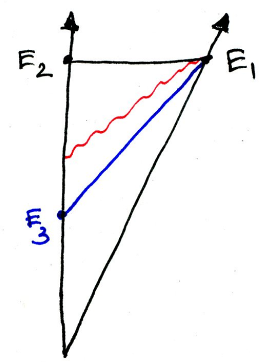

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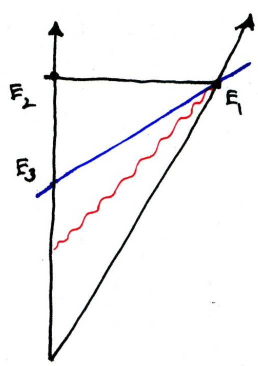

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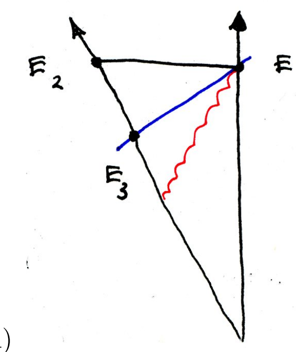

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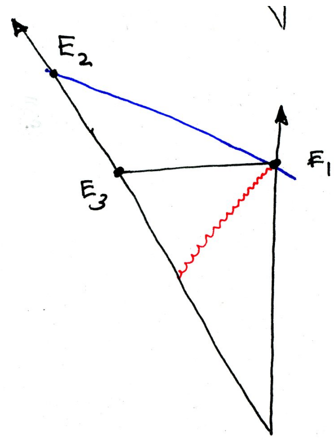
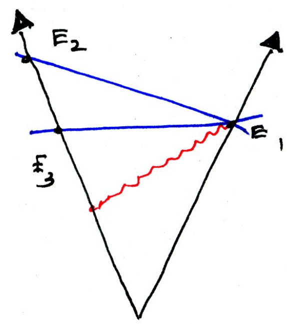


(e)

(22) What does the space-time diagram of the history look like from Alice's frame?



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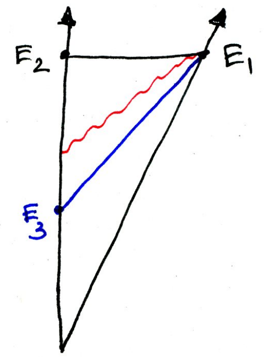

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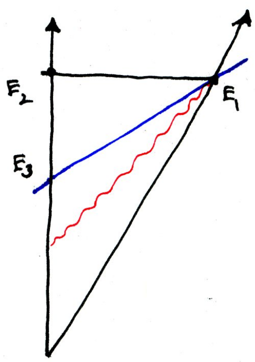

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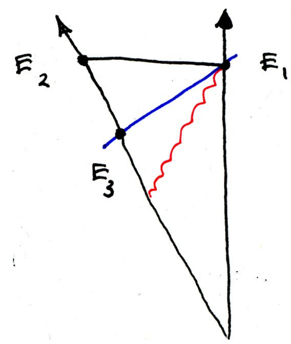

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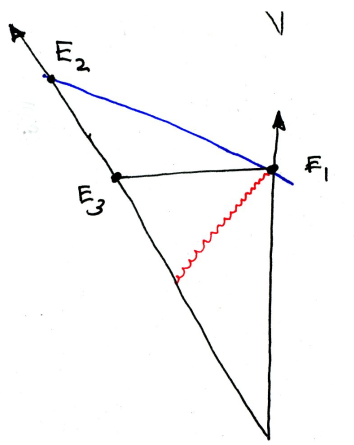


(e)

(23) What day in Bob's frame is simultaneous, according to Alice, with the arrival of Bob's "Happy Birthday" jingle? Another way of asking this is, what is the time of event E_3 according to Bob's clocks?

(a) 16/25 of a year, on about July 20.
(b) 9/25 of a year, on about April 10.
(c) 3/5 of a year or about July 6.
(d) 1/5 of a year or about February 11.
(e) 1 year or January 1.

(24) You zip by the Berne clock tower at $v = 3/5c$ (so $\gamma = 5/4$). According to your measurements, one second in the tower's frame takes how long?
  (a) $5/4$ s $= 1.25$ s since the tower is moving relative to your frame and "moving clocks run slow".
  (b) $4/5$ s $= 0.8$ s since you're moving and "moving clocks run slow".
  (c) at the same rate as your proper time ("your clock time").
  (d) none of the above.

(25) Suppose you move *away* from the Berne clock tower at $v = 3/5c$ (so $K = 2$). The reading of the clock - what you see on the clock face as it appears in your frame - runs
  (a) slow because the clock is running slow - "moving clocks run slow".
  (b) slow because the light has further to go.
  (c) fast because the light has less far to go.
  (d) fast because you are moving.
  (e) at the same rate as your proper time ("your clock time").

(26) Suppose you move *toward* the Berne clock tower at $v = 3/5c$ (so $K = 1/2$. The reading of the clock, as it appears in your frame, runs
  (a) slow because the clock is running slow - "moving clocks run slow".
  (b) slow because the light has further to go.
  (c) fast because the light has less far to go.
  (d) fast because you are moving.
  (e) at the same rate as your proper time ("your clock time").

(27) So is the clock running slow or not?
  (a) Yes.
  (b) No.
  (c) It is actually running fast.

(28) Events are "spatially separated" or "space-like" if
  (a) it is not possible to make a world-line pass through both events.
  (b) the events are simultaneous in some reference frame.
  (c) one is on the left of the other on a space-time diagram.
  (d) (a) and (b)
  (e) (a), (b) and (c)

(29) The clocks in Tetsuya's frame read different times because
  (a) The speed of light in vacuum is the same for all observers
  (b) Events do not depend on the frame in which they are described.
  (c) (a) and (b)
  (d) there is an error in the diagram

(30) (This question is about the logical structure of the argument.) The length L_T is shorter than D_T because
  (a) we just make an assumption.
  (b) we have to leave open the possibility that the lengths are different.
  (c) simultaneous events in Aki's frame are not simultaneous in Tetsuya's frame.
  (d) they just appear shorter. They are actually the same length.

(31) Ladder in barn "paradox" version 1 "smooth sailing": What's the proper description?
  (a) It's obvious, the ladder just fits.
  (b) The barn is too short to hold the ladder
  (c) In special relativity, different observers can't agree on the ordering of spatially separated events.

(d) Simultaneity, simultaneity, simultaneity! The events of the ends of the ladder reaching the ends of the barn are not simultaneous in all frames.

(32) Ladder in barn "paradox" version 2 "Quick, shut the doors!": What's the proper description?
  (a) It's obvious, the ladder just fits and the doors close.
  (b) The doors close just fine but then the ladder busts through the front door.
  (c) It is not possible to close the front door. The ladder sticks out.
  (d) It is not possible to close either door.
  (e) Oh, wait! This involves acceleration doesn't it? Special relativity doesn't describe accelerating systems.

(33) What is the description of events in the muon frame?
  (a) Time runs slowly on earth so the half-life is now approximately 11 μs and more particles make it to sea level.
  (b) The atmosphere is contracted to a depth of approximately 20 km / 7 or 2.8 km, hence the fraction f is still about 6.2.
  (c) The observers disagree. The resolution is left up to experiment.
  (d) The muons never make it to the earth's surface because the half-life is 1.52 μs in their rest frame.
  (e) The atmosphere is dilated to a depth of approximately 1420 km and the fraction f is now a bit over 2000.

(34) Two identical rockets are connected by a 400 m cable. Joyce is in the rocket on the rocket in the front (right side). James occupies the rocket in the rear (left side). Initially they are at rest with respect to Tolstoy, an observer in a third spaceship. Simultaneously, at $t = 0$ in this frame, Joyce and James fire their rockets along the direction of the cable and accelerate to $v = \frac{4}{5}c$ and $\gamma = 5/3$. Does the cable break?
  (a) The cable breaks.
  (b) The cable doesn't break.
  (c) Since the different observers disagree, special relativity does not tell us what happens.
  (d) Oh, wait! This involves acceleration doesn't it? Special relativity doesn't describe accelerating systems.

(35) According to Tolstoy, what is the expected final length of the cable?
  (a) 400 m
  (b) 320 m
  (c) 500 m
  (d) 240 m

(36) Tied rockets: What is the description in Joyce's frame?
  (a) James jumps the gun and starts engines too early.
  (b) James is a deadbeat. He doesn't start his engines until Joyce has already moved away.
  (c) Tolstoy doesn't tell the whole story. Joyce knows that James doesn't agree on the time; they can't synchronize their clocks in the original frame.
  (d) Oh, wait! This involves acceleration doesn't it? Special relativity doesn't describe accelerating systems.

(37) So we have seen that the momentum transforms from one frame to another as $P' = P - Mw$. What changes in the relation between the masses,

$$\frac{v_1^A - v_1^B}{v_2^A - v_2^B} = -\frac{m_2}{m_1}$$

?
  (a) Nothing since the factors with w divide out.
  (b) Nothing since the terms with w cancel out.

(c) Nothing. How could it? The masses don't change (non-relativistically)!
(d) Something. It is complicated but there's w junk left over.
(e) If the transformation moves from the m_1 mass toward the m_2 mass then the m_2 mass increases.

(38) Does all this hold in special relativity?
(a) No. We assumed non-relativistic velocity addition.
(b) Yes. Everything is fully relativistic.
(c) No. Velocity doesn't make any sense in special relativity since we can switch frames.
(d) Yes. We only have to modify energy.

(39) What does "momentum is conserved " mean?
(a) The sum of all momenta before and after any physical process are equal.
(b) The momenta of a particle before and after any physical process are equal.
(c) If the momentum is some number in one frame, it is the same number in any frame moving respect to the first frame.
(d) If the momentum is some number in one frame then it is equal to some other number, as determined by a formula.
(e) The total momentum in any frame and at any time is the same number.

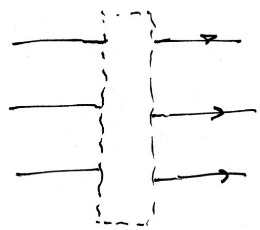
(40) What does a quantity "transforms as " mean?
(a) The quantities before and after any physical process are equal.
(b) The quantities intrinsic to a particle before and after any physical process are equal.
(c) If the quantity is some number in one frame, it is the same number in any frame moving respect to the first frame.
(d) If the quantity is some number in one frame then it is equal to some other number, as determined by a formula involving the relative velocity of the frames.
(e) The quantity is the same number in any frame and at any time.

(41) If P and P^0 are conserved in Avery's frame then are P' and $P^{0\prime}$ conserved in Basil's frame?
(a) No. We assumed non-relativistic velocity addition.
(b) No, since w is in the transformed results.
(c) Yes. The transformed results only depend on the conserved P and P^0 and the constant w, the frame speed.
(d) Yes, since they are equal.

(42) The interpretation of $E = mc^2$ is best put as
(a) Mass and energy are the same thing.
(b) Since mass is no longer conserved in physical processes, mass may be created or destroyed as long as the difference in kinetic energy is equal to the difference in mass times c^2,
(c) Since momentum is no longer conserved in physical processes, mass may be created or destroyed as long as the difference in kinetic energy is equal to the difference in mass times c^2,
(d) Energy weighs something.
(e) Since mass is no longer conserved in physical processes, mass may be only created as long as the difference in kinetic energy is equal to the difference in mass times c^2,

(43) You have two potatoes that weigh exactly the same. You bake one for dinner. Right before you start to weigh your hot potato. The result is
(a) slightly more than the cold potato
(b) slightly less that the cold potato
(c) the same as the cold potato
(d) vastly more than the cold potato
(e) vastly less than the cold potato

(44) Which sketch of a magnetic field of a magnet most closely resembles yours?



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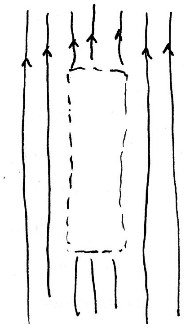

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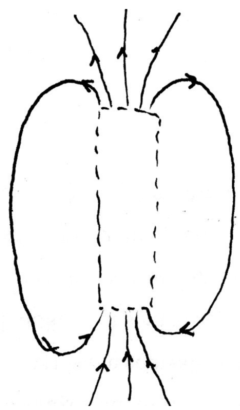

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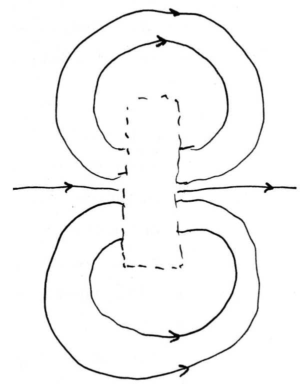


(d)

(45) Is it possible to construct projections $+m_B$ or $-m_B$ of one arrow for all axes?
- (a) Yes, they are at right angles.
- (b) Yes, but it is hard to draw
- (c) No way.
- (d) No, I can prove it geometrically
- (e) We need more information before it is possible to determine the correct answer.

(46) What would be outcome of the repeated Stern-Gerlach experiment 4.1?
- (a) $+m_B$ 50 % of the time and $-m_B$ 50 % of the time
- (b) $+m_B$ 100 % of the time
- (c) $-m_B$ 100 % of the time
- (d) $+m_B$ 75 % of the time and $-m_B$ 25 % of the time
- (e) None of the above

(47) What would be outcome of the repeated Stern-Gerlach experiment 4.2?
- (a) $+m_B$ 50 % of the time and $-m_B$ 50 % of the time
- (b) $+m_B$ 100 % of the time
- (c) $-m_B$ 100 % of the time
- (d) $+m_B$ 75 % of the time and $-m_B$ 25 % of the time
- (e) None of the above

(48) What would be outcome of the repeated Stern-Gerlach experiment 4.3?
- (a) $+m_B$ 50 % of the time and $-m_B$ 50 % of the time
- (b) $+m_B$ 100 % of the time
- (c) $-m_B$ 100 % of the time
- (d) $+m_B$ 75 % of the time and $-m_B$ 25 % of the time
- (e) None of the above

(49) What would be outcome of the “30-60” repeated Stern-Gerlach experiment?
  (a) $+m_B$ 50 % of the time and $-m_B$ 50 % of the time
  (b) $+m_B$ 100 % of the time
  (c) $-m_B$ 100 % of the time
  (d) $+m_B$ 25 % of the time and $-m_B$ 75 % of the time
  (e) $+m_B$ 75 % of the time and $-m_B$ 25 % of the time

(50) Referring to the chart of probability as a function of angle θ, what would be outcome of the “$\theta = 45$” degrees repeated Stern-Gerlach experiment?
  (a) $+m_B$ 50 % of the time and $-m_B$ 50 % of the time
  (b) $+m_B$ 100 % of the time
  (c) $-m_B$ 100 % of the time
  (d) $+m_B$ 15 % of the time and $-m_B$ 85 % of the time
  (e) $+m_B$ 85 % of the time and $-m_B$ 15 % of the time

(51) Referring to the chart of probability as a function of angle θ, what would be outcome of the “$\theta = 37$” degrees repeated Stern-Gerlach experiment?
  (a) $+m_B$ 100 % of the time
  (b) $-m_B$ 100 % of the time
  (c) $+m_B$ 90 % of the time and $-m_B$ 10 % of the time
  (d) $+m_B$ 10 % of the time and $-m_B$ 90 % of the time
  (e) None of the above

(52) In a role of a die, what is the probability of obtaining an outcome that is less than or equal to 4?
  (a) $P(x \leq 4) = \frac{1}{6}$ - about 17%
  (b) $P(x \leq 4) = 4 \times \frac{1}{6} = \frac{2}{3}$ - about 67%
  (c) $P(x \leq 4) = \left(\frac{1}{6}\right)^4 = 7.71 \times 10^{-4}$ - about 0.08%
  (d) This can’t be determined from the info given

(53) As forecast on Monday (November 3) morning, the likelihood of precipitation on Election Day, Tuesday November 4, is 10 % for each 3 hour interval. For instance, the probability of precipitation from 10 AM to 1 PM is 10 %. Similarly for the rest of the day. So for the entire 24 hour period, what is the probability of precipitation?
  (a) You multiply the hourly forecasts so you get $0.1^8 = 1 \times 10^{-8}$ so 1×10^{-6} % of the time. Essentially, it *will not* rain today.
  (b) You add the hourly forecasts so you get $0.1 \times 24 = 2.4$ so 240 % of the time. Essentially, it *is* raining!
  (c) You take one hourly interval and use that. There is a 10 % chance of rain for the 24 hour period.
  (d) The chance it will not rain in one 3 hour interval is 90% so for the whole day we have $1 - (0.9)^8 \approx 0.57$. Roughly, there is a 60% chance of rain.
  (e) None of the above

(54) In a toss of two dice, what is the probability that the sum of the outcomes is 6?
  (a) $P(x_1 + x_2 = 6) = \frac{1}{36}$ - about 3%
  (b) $P(x_1 + x_2 = 6) = \frac{1}{18}$ - about 6%
  (c) $P(x_1 + x_2 = 6) = \frac{5}{36}$ - about 14%
  (d) $P(x_1 + x_2 = 6) = \frac{1}{9}$ - about 11%
  (e) This can’t be determined from the info given

(55) For the initial state $m_z = +m_B$ going into the switching Stern-Gerlach apparatus, what is the probability of the $+m_B$ outcome, given the axis c?
  (a) $P(+|c) = \frac{1}{4}$

(b) $P(+|c) = 1$
(c) $P(+|c) = \frac{1}{2}$
(d) $P(+|c) = \frac{3}{4}$
(e) This can't be determined from the info given

(56) For the switching Stern-Gerlach apparatus, what is the probability of the $+m_B$ outcome, given each of the axes a, b, c are equally likely?
(a) $P(+m_B) = \frac{1}{4}$
(b) $P(+m_B) = 1$
(c) $P(+m_B) = \frac{1}{2}$
(d) $P(+m_B) = \frac{1}{3}$
(e) $P(+m_B) = \frac{1}{6}$

(57) You have a friend who gives two of you boxes to take to Phoenix and Chicago. She tells you that the boxes contain giant pumpkin 6 seeds. Once you are in Chicago you open the box and see 2 seeds. How many are in the box in Phoenix?
(a) 4
(b) 4
(c) 4
(d) This can't be determined from the info given

(58) Instantaneously and certainly your know the number of these giant pumpkin seeds in Phoenix. Does this mean that there is faster-than-light signals between Chicago and Phoenix?
(a) Yes, otherwise the state in Phoenix would not determined.
(b) No, the only thing that changed was your knowledge of a previously existing situation.
(c) Yes, the signal kept the number of seeds updated
(d) No, reality is decided moment by moment. For instance, in an alternate universe you would have seen 3 seeds.

(59) In the original EPRB experiment does Alice know the results of Bob's experiments with certainty (probability of 1)?
(a) Yes.
(b) No.
(c) Yes, but only after she has taken her measurements.
(d) No, since she does have access to Bob's distant analyzer.

(60) Can the EPR experiment be used to communicate?
(a) Yes.
(b) No.
(c) Yikes! I don't know.

(61) Are these EPR experiments consistent with special relativity?
(a) Yes.
(b) No.

(62) What is the probability for case VIII?
(a) 1
(b) 1/2
(c) 5/9
(d) 0
(e) 1/4
(f) None of the above

(63) How many trials would you have to run to distinguish these two cases?

(a) Since

$$0.06 = \frac{1}{\sqrt{N}}$$

it would be about $N = 300$ (a "one sigma result")

(b) To be really confident I'd like

$$0.028 = \frac{1}{\sqrt{N}}$$

it would be about $N = 1300$ (a "two sigma result")

(c) Yikes! I don't know.

(64) What are the results of the taste testing of the quantum cakes? Let's use local determinism/realism. For this testing Lucy and Ricardo do not check early and the cook is certainly not informed. How frequently would we expect both cakes to taste good?
(a) 100 % good
(b) 9 % good
(c) ≥ 9 % good
(d) 0 % good
(e) 50 % good
(f) None of the above

(65) Using the new Stern-Gerlach interferometer of chapter 9 and shown on the board, we block off the $m_x = -m_B$ path through the device. What is the probability that an atom makes it to point C, given we stared with the state $m_z = +m_B$ at A?
(a) $P(C|m_z = +m_B, A) = \frac{1}{2}$
(b) $P(C|m_z = +m_B, A) = \frac{1}{4}$
(c) $P(C|m_z = +m_B, A) = \frac{1}{8}$
(d) $P(C|m_z = +m_B, A) = 1$
(e) None of the above

(66) Using the Stern-Gerlach interferometer, we block off the $m_x = +m_B$ path through the device. What is the probability that an atom makes it to point C, given we stared with the state $m_z = +m_B$ at A?
(a) $P(C|m_z = +m_B, A) = \frac{1}{2}$
(b) $P(C|m_z = +m_B, A) = \frac{1}{4}$
(c) $P(C|m_z = +m_B, A) = \frac{1}{8}$
(d) $P(C|m_z = +m_B, A) = 1$
(e) None of the above

(67) Using the Stern-Gerlach interferometer, leave both paths open. What is the probability that an atom makes it to point C, given we stared with the state $m_z = +m_B$ at A?
(a) $P(C|m_z = +m_B, A) = \frac{1}{2}$
(b) $P(C|m_z = +m_B, A) = \frac{1}{4}$
(c) $P(C|m_z = +m_B, A) = \frac{1}{8}$
(d) $P(C|m_z = +m_B, A) = 1$
(e) None of the above

(68) With really dim light so there are too few photons to scatter off the atoms, what result do you find?What is the probability that an atom makes it to point C?
(a) $P(C|m_z = +m_B, A) = \frac{1}{4}$
(b) Two cases: $P(C|m_z = +m_B, A) = \frac{1}{4}$ if there is a glint and $P(C|m_z = +m_B, A) = 1$ if there is no glint.

(c) Two cases: $P(C|m_z = +m_B, A) = \frac{1}{2}$ if there is a glint and $P(C|m_z = +m_B, A) = 1$ if there is no glint.
(d) $P(C|m_z = +m_B, A) = 1$
(e) None of the above

(69) You ask a whale to watch the paths, using light that will allow the whale to see the glint of light (or the shadow) from the atom passing through one path or the other. What is the probability that an atom makes it to point C, given we stared with the state $m_z = +m_B$ at A?
(a) $P(C|m_z = +m_B, A) = \frac{1}{2}$
(b) $P(C|m_z = +m_B, A) = \frac{1}{4}$
(c) $P(C|m_z = +m_B, A) = \frac{1}{8}$
(d) $P(C|m_z = +m_B, A) = 1$
(e) None of the above

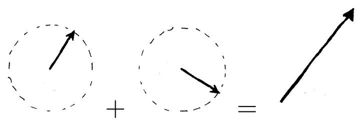
(70) Using a pair of Stern-Gerlach interferometers, suppose we block path "2a" only. What is the probability that an atom makes it to point C, given we stared with the state $m_z = +m_B$ at A? [C is next to the "+" exit of the second interferometer.)
(a) $P(C|m_z = +m_B, A) = \frac{1}{2}$
(b) $P(C|m_z = +m_B, A) = \frac{1}{4}$
(c) $P(C|m_z = +m_B, A) = 0$
(d) $P(C|m_z = +m_B, A) = 1$
(e) None of the above

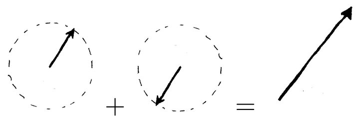
(71) Using a pair of Stern-Gerlach interferometers, suppose we block path "1a" only. What is the probability that an atom makes it to point C, given we stared with the state $m_z = +m_B$ at A?
(a) $P(C|m_z = +m_B, A) = \frac{1}{2}$
(b) $P(C|m_z = +m_B, A) = \frac{1}{4}$
(c) $P(C|m_z = +m_B, A) = 0$
(d) $P(C|m_z = +m_B, A) = 1$
(e) None of the above

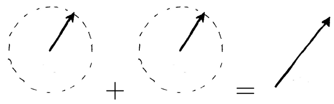
(72) What is the state at C?
(a) $m_z = +m_B$
(b) $m_z = -m_B$
(c) $m_x = +m_B$
(d) $m_x = -m_B$
(e) None of the above

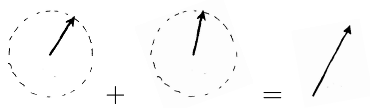
(73) Using a pair of Stern-Gerlach interferometers, suppose we block paths "1a" and "2b". What is the probability that an atom makes it to point C, given we stared with the state $m_z = +m_B$ at A?
(a) $P(C|m_z = +m_B, A) = \frac{1}{2}$
(b) $P(C|m_z = +m_B, A) = \frac{1}{4}$
(c) $P(C|m_z = +m_B, A) = 0$
(d) $P(C|m_z = +m_B, A) = 1$
(e) None of the above

(74) The next collection of electrons away from the center of the screen - the first "interference fringe" - should arrive on the screen at a distance determined by which orientation of the Path II stopwatch?

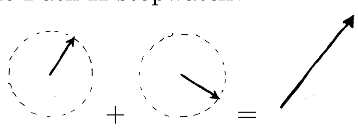
(a) 

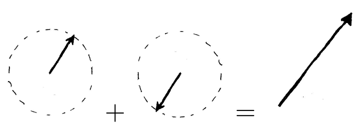
(b) 

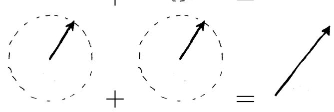
(c) 

(d) 

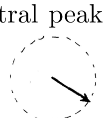
(75) The first location where the probability of arrival vanishes is determined by which orientation of the Path II stopwatch?

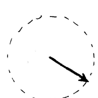
(a) 

(b) 

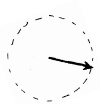
(c) 

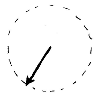
(d) 

(76) The central peak is determined by the amplitudes of the two paths being oriented the same way, say . Consider the center of the third peak away from the center. If the amplitude for the shorter path was now , what would the amplitude for the longer path be?

(a) 

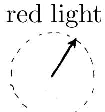
(b) 

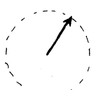
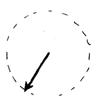
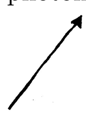
(c) 

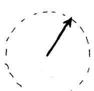
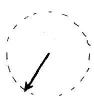
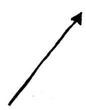
(d) 

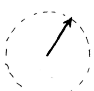
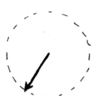
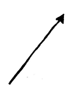
(e) 

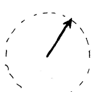
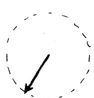
(77) How many rotations will the amplitude for the second path undergo as we move from the central peak to the third peak?
(a) 0
(b) > 1 but < 2
(c) > 2 but < 3
(d) > 3 but < 4
(e) > 4

(78) In the single-photon interference experiment there are two paths, one for each arm of the interferometer. The amplitude for a photon of red light to travel through the interferometer on Path I to one particular spot on the screen is . For Path II the amplitude is . The total amplitude for the photon to land at this spot on the screen is

(a)  +  = 

(b)  +  = 

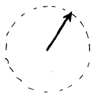
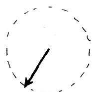
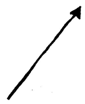
(c)  +  = 

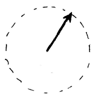
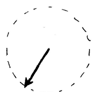
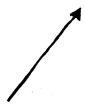
(d)  +  = 

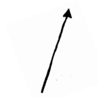
(79) The total probability is then
(a) 0
(b) 1
(c) 1/2
(d) 1/4
(e) None of the above.

(80) In the single-photon interference experiment the amplitude for a photon of red light to travel through the interferometer on Path I to a different spot on the screen is . For Path

II the amplitude is  . The total amplitude for the photon to land at this spot on the screen is

(a)  +  = 

(b)  +  = 

(c)  +  = 

(d)  +  = 

(e) None of the above

(81) In Experiment 2 of the delayed choice series, what do you predict for the detectors as the mirror is moved?

(a) Since the Path I length changes then I would expect an interference pattern in the photon counts.

(b) Since mirror I is moving, we have which way information so there would be pure anti-correlation - no interference.

(c) There would be a 50/50 chance of the photon going on each path and this is what the detectors would pick up.

(d) Since the photon “sees” a wave-like experiment, it will behave as a wave. There will be interference.

(e) None of the above

(82) In Experiment 3 of the delayed choice series, what do you predict for the detectors as the mirror is moved? Recall that the second beam splitter is moved randomly, well after the photon should have passed the first beam splitter.

(a) Since the Path I length changes then I would expect an interference pattern in the photon counts, always.

(b) Once the photon is in the interferometer, if he second beam splitter is in place then I would expect an interference pattern, since which-way information is lost and since the Path I length changes with the mirror.

(c) Since we *might* have which way information then the photons behave as a particle all the time.

(d) As the photon approaches the first beam splitter if it “sees” a wave-like experiment, it will behave as a wave. If it “sees” a particle-like experiment, it will behave as a particle.

(83) Does the EPRB experiment provide the necessary random and shared key for the Vernam cipher?

(a) Yes, since the EPRB results are random and because Bob can simply reverse the encoding rule.

(b) No, since the key is not shared.

(c) No, since the results are not random
(d) It only works some of the time.

(84) Does the EPRB experiment provide a secure way to share a key for the Vernam cipher?
(a) Yes, since Eve could not measure the EPR state.
(b) Yes, since the results are random
(c) No, since Eve would necessarily change the state and Bon would detect her eavesdropping.
(d) No, since Eve could simply use an analyzer oriented in the same direction as Alice and Bob to read the key.