Name ______________________________________ **Student ID Number** _____________

last *first*

PHYS 110 Midterm #1

No phone/computer/internet usage is allowed. For multiple choice questions, please circle the best answer.

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1) How did Eratosthenes determine the size and shape of the Earth?

A) Due to solar eclipses appearing at different times of day in Alexandria and Syene, Eratosthenes was able to determine that the Earth was round. By pacing off the North-South distance between the cities and knowing the difference in time of the eclipses, he was able to measure the size of the Earth to ~1% accuracy.

B) Eratosthenes heard reports that in the city of Syene the sun cast no shadow and could be seen at the bottom of a well at noon on the longest day of the year. Since the sun did cast a shadow on the longest day of the year in Alexandria, this meant the Earth must be round. Eratosthenes hired people to pace off the North-South distance between Alexandria and Syene, and with measurements of the angle of shadow in Alexandria made an accurate (~1%) measurement of the size of the Earth.

C) Due to the shadow of the Earth during eclipses of the moon, a spherical shape for the Earth was deduced. By measuring the apparent size of the shadow Eratosthenes was able to determine the ratio of the Moon and Earth's sizes. An accurate measure of the Earth's size had to wait for Magellan's circumnavigation of the globe.

D) By looking at the eclipses of Jupiter's moons with a rudimentary telescope, Eratosthenes was able to tell the difference in longitude between Alexandria and Syene. By pacing off the East-West distance between the cities and knowing the difference in time of the Jovian eclipses, he was able to measure the size of the Earth to ~1% accuracy.

2) How does GPS work?

A) Your phone sends a radio message to three or more GPS satellites and times how long the message takes to travel to each satellite and back. Since the speed of light is constant, the round-trip times of the messages tells your phone where it is relative to the satellites. Because the positions (orbits) of the satellites are known this enables your phone to triangulate its position.

B) Your phone sends a radio message with the time to one GPS satellite. The satellite can see the direction of the signal and the time delay compared to its onboard atomic clock, and radios back the location of your phone. Repeating with more satellites can improve the precision.

C) The GPS satellites are used to give very accurate time to the cell phone towers, which then repeat this time via radio signals. Like using talking clocks in your backyard, by timing the difference in arrival time of the signals from three or more cell phone towers your phone can determine its position.

D) Each GPS satellite broadcasts the time of the onboard atomic clock, along with its identifying satellite number. Your phone listens for signals from three or more satellites. Because the speed of light is constant the time delay allows your phone to measure the distance to each satellite. Since the positions (orbits) of the satellites are known this enables your phone to triangulate its position.

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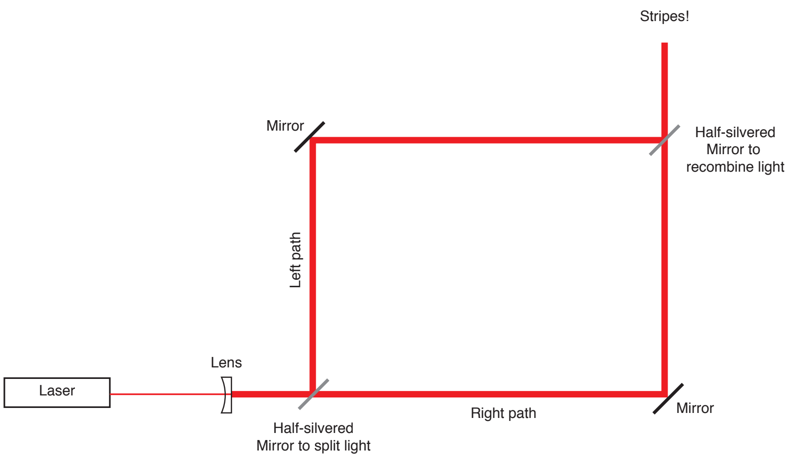
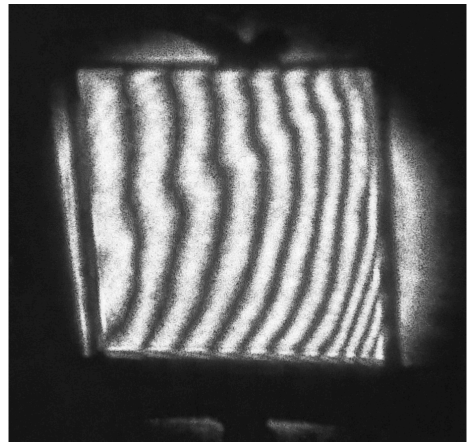
The below diagram shows the laser interferometer we studied in class, with a photograph of the stripes shown to the right. These diagrams are used for questions 3, 4, & 5.





3) I can block the left path, right path, or neither. Which answer accurately describes what we see and why?

A) If both paths are open we see stripes because the waves interfere (add or cancel). If either the left or right paths are blocked we see just a smooth patch of light because there is no mixing of waves from the two paths.

B) If both paths are open we see stripes because the waves interfere (add or cancel). If either the left or right paths are blocked we see a laser dot in the middle because light moves like a particle.

C) If either the left or right paths are blocked we see the stripes of a wave. If both paths are open we see a smooth patch of light because the waves cancel out.

D) The stripes are created by bouncing off the first mirror, so only the light in the left path has stripes. So if we block the left path we see a smooth patch of light, but if we block the right path the stripes become clearer.

4) We arrange the blocking or unblocking of the paths so that we see stripes, and then turn the brightness of the red laser down **very** low so that it emits one photon of light at a time. We then use an expensive camera that can detect how hard each photon hits. Which answer accurately describes what we see and why?

A) We see a faint pointillism painting of individual photons hitting the screen. Because the photons are particles they all hit with the same strength and appear randomly across the screen to make a smooth featureless image.

B) Because particles move like waves, the detector sees each photon hit across the whole detector—the entire stripe pattern strobes with the arrival of each photon.

C) We see a faint pointillism painting of individual photons hitting the screen. The photons appear randomly across the screen, but hit hardest in the bright stripes and very weakly in the dark stripes.

D) We see a faint pointillism painting of individual photons hitting the screen. The detector measures each photon as hitting with the same strength, with more photons hitting in the bright stripes and few to no photons hitting in the dark stripes.

5) Keeping the expensive camera, we replace the faint red laser with a faint blue laser. Which answer accurately describes what we see and why?

A) Because all particles move like waves, we see exactly the same results as in question 4.

B) We see a faint pointillism painting of individual photons hitting the screen. Compared to the faint red laser, the stripes with the blue laser are closer together and the hit of each blue photon is harder.

C) We see a faint pointillism painting of individual photons hitting the screen. Because all particles move like waves the stripes are unchanged but the hit of each blue photon is harder.

D) The stripes appear the same, but because the blue photons have more energy the image appears more like a pointillism painting.

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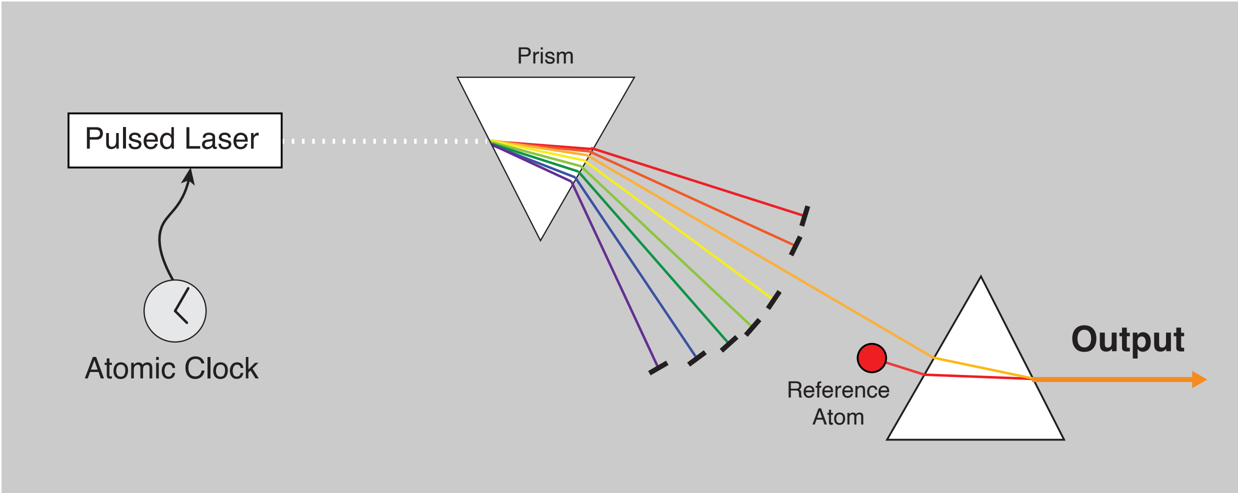

6) The above diagram shows the basic layout of an optical clock, with the light from an optical comb being combined with the light from a reference atom. Which answer accurately describes what we see at the output and why?

A) The beam from the optical comb (orange) is pulsed in sync with the atomic clock, and mixes with the steady light from the reference atom to make a steady output of intermediate color. The color of the output tells us the difference in frequency of the reference atom and allows us to count very fast.

B) The beam from the optical comb (orange) is steady in time and at a stable known frequency (color). When combined with the light from the reference atom the brightness of the output beats in time. The speed of the output beats indicate the difference in frequency of the light from optical comb and the reference atom, and allows us to count very fast.

C) The beam from the optical comb (orange) is steady in time and at a stable known frequency (color), and mixes with the steady light from the reference atom to make a steady output of intermediate color. The color of the output tells us the difference in frequency of the reference atom and allows us to count very fast.

D) The beam from the optical comb (orange) is pulsed in sync with the atomic clock. When mixed with the light from the reference atom the timing of the beats is shifted by the difference in color. This shift in beat timing allows us to count very fast.

7) Above is a photograph of a shadow analemma. What best describes the analemma?

A) An analemma marks the position of the sun shadow at the same clock time each day. The movement in the long direction traces the elevation of the sun with the seasons, with summer at the bottom (short shadow) and winter at the top (long shadow). Because the Earth's orbit is elliptical, the length of the days are not constant. The movement in the wide direction traces the difference between solar time and clock time, with the sun being a little ahead or behind depending on time of year.

B) An analemma marks the position of the sun shadow as it passes directly overhead each day. The movement in the long direction traces the elevation of the sun with the seasons, with summer at the bottom (short shadow) and winter at the top (long shadow). The movement in the wide direction indicates the difference in length of day.

C) An analemma traces the position of sunrise and sunset each day. The movement in the long direction traces where the sun sets along the horizon with summer at the top and winter at the bottom. The movement in the wide direction shows that summer days are longest in the summer and shortest in November and February.

D) An analemma traces the position of the sun shadow over the course of the summer and winter solstices. The movement in the long direction (down arrows) traces the elevation of the sun as it rises during the summer solstice, and the up arrows trace its path on the winter solstice.

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Essay Question

Imagine you are a ship's navigator in the early 1800's, setting out from London. Starting with the noon dropping of the ball on the astronomy tower (viewable from the harbor), describe how you can use observations of the stars while at sea to determine your position both north/south (latitude) and east/west (longitude). You will be graded on both the accuracy and clarity of your answer.

(You can type your answer in here, or you can email me miguelfm@uw.edu a photograph of your handwritten essay and/or accompanying diagrams. If you are emailing me for all or part of your answer, please indicate that in the answer box below, and please put your name in the email and send from your uw.edu email account.)