Name ______________________________________ **Student ID Number** _____________
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PHYS 110 Midterm #1

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

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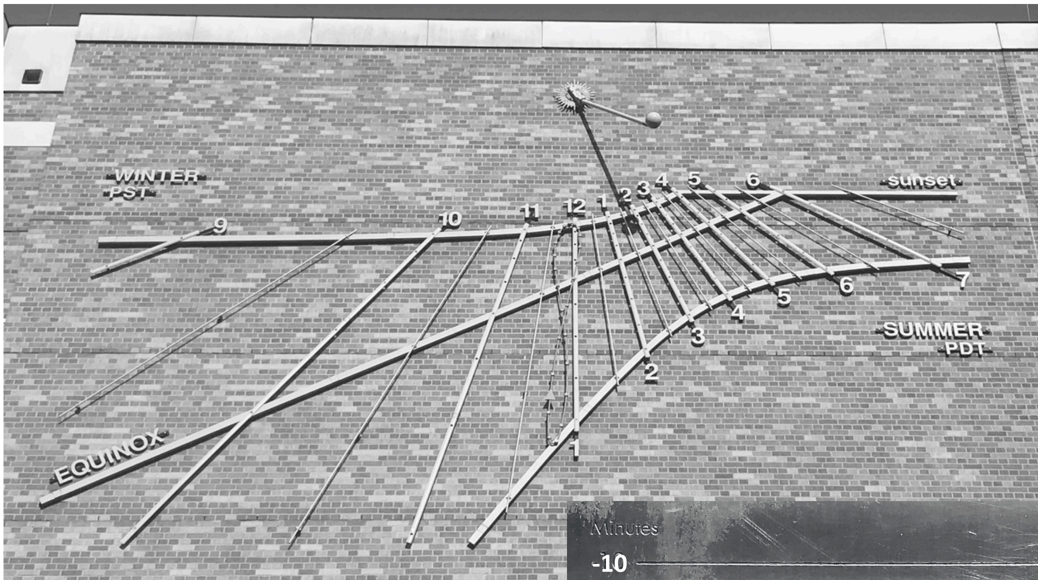

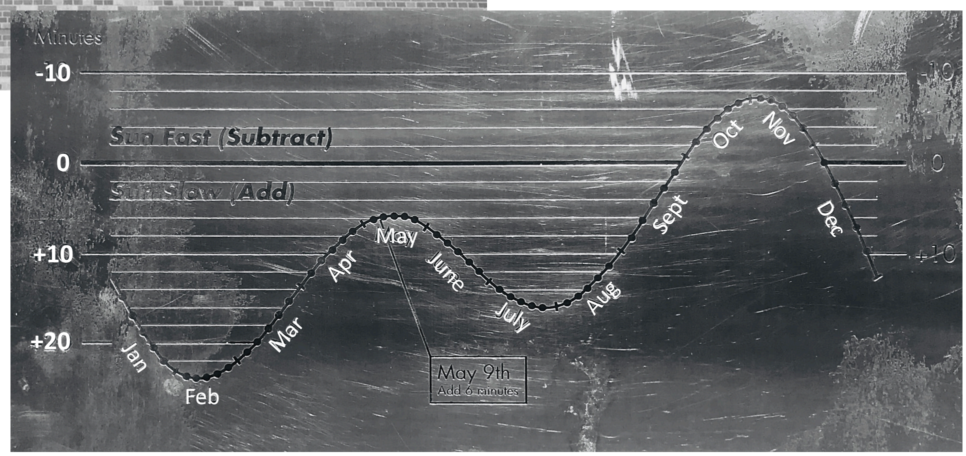

1) The above photo of the sundial on the Physics and Astronomy building was taken on a sunny day during the first six months of the calendar year (Jan-June). How can the sundial be used to determine the time (as read by a modern clock)?

   A) **2:03 pm.** The shadow of the gnomon ball appears high on the wall, near the winter solstice line (upper curve), so the local solar time is at about 1:40 PST. The gnomon shadow is a bit below the solstice line, so by referring to the analemma the date should be the winter solstice ±5 weeks. This implies the photo was taken in either mid ~~November~~ or late January. Using either the time correction inset or the analemma we can adjust the local time by +23 minutes to obtain 2:03 clock time.

   B) **2:46 pm**. The shadow of the gnomon ball appears high on the wall, near the summer solstice line (upper curve), so the local time is at about 2:40 PDT. The gnomon shadow is a bit below the solstice line, so by referring to the analemma the date should be the summer solstice ±5 weeks. This implies the photo was taken in either mid May or late ~~July~~. Using either the time correction inset or the analemma we can adjust the local time by +6 minutes to obtain 2:46 clock time.

   C) **2:46 pm**. The shadow of the gnomon ball appears high on the wall, near the 2 hour mark. As the shadow is much closer to the 2 hour mark on the top line than the 3 hour mark on the bottom line, the local time is 2:03. Assuming this is a recent picture, we should add 23 minutes to the local time using the correction inset to obtain 2:46 pm.

   D) **2:40 pm.** The shadow of the gnomon ball appears high on the wall, near the summer solstice line (upper curve) so the local time is at about 2:40 PDT. The time corrections are for determining the local time, not the clock time, so no correction is needed.

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2) You are the navigator with George Vancouver, and at right is a picture of the Arnold marine chronometer (#176) you took on the voyage when he mapped the Puget Sound in 1792. How did you use this chronometer and astronomical observations for navigation?

A) Before leaving London in 1790, you set the chronometer to the local time in London (aided by local astronomers using a transit telescope). At sea you use a sextant to measure the elevation of the north star, giving you your latitude. You then use the sextant to measure the elevation of a star near the eastern horizon (and the date) to determine the local time. The difference between your local time and the London time indicated by the chronometer gives your current longitude.

B) The elevation of the north star gives you your latitude. While at sea you can measure the local time with a transit telescope and use that to set the marine chronometer. When you return to London you can compare the time on the chronometer with the local time to determine the longitude.

C) Due to the tilt of the Earth and its orbit, the shape of the analemma changes with latitude and longitude. By measuring where the sun rises on the eastern horizon one can determine latitude, and by measuring when it rises with the marine chronometer (along with the date) will determine the longitude.

D) Before leaving London in 1790, you set the chronometer to the local time in London (aided by local astronomers using a transit telescope). This tells you when the lunar eclipses will occur as seen in London. By measuring the local time of the lunar eclipses and comparing to when they occur in London you can measure the longitude. A sextant can then be used to measure the elevation of the north star, giving you your latitude.

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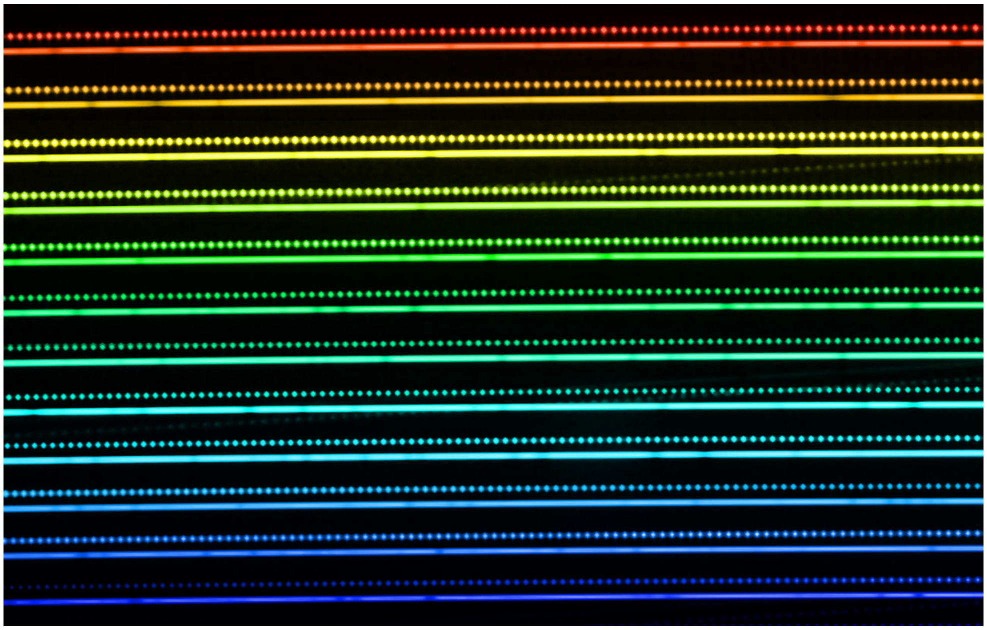

3) An 'astrocomb' spectrometer image is shown above containing the light of a frequency comb (upper line) and a star (lower line) after sending both through a echelle spectrometer (fancy prism). While this image is black and white, the image shown in class shows the colors going through the rainbow, with red at upper right and blue/violet at lower left. Describe how the light of the frequency comb is made and appears in the astrocomb spectrum at right.

A) The light from many fancy lasers is passed through a prism to make `beats' of light. This can then be passed into the astrocomb which separates the light back into the constituent colors of the original lasers. The light in each dot of the astrocomb appears steady in time.

B) An atomic clock is used to time out pulses of light, each pulse with a unique color. These colors then appear as pulsing dots in the astrocomb.

C) An atomic clock is used to time out pulses of white light. The light in each dot of the astrocomb appears steady in time.

D) The light from each dot can be combined with the light of a reference atom to allow the beats to be counted. This creates an accurate clock for finding planets.

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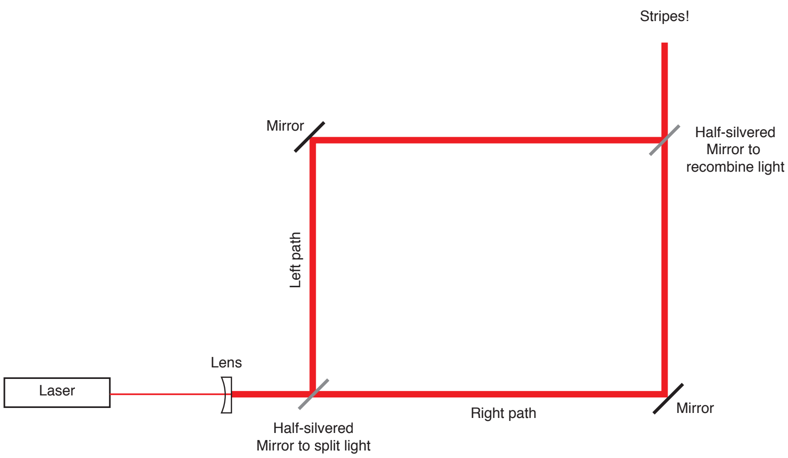
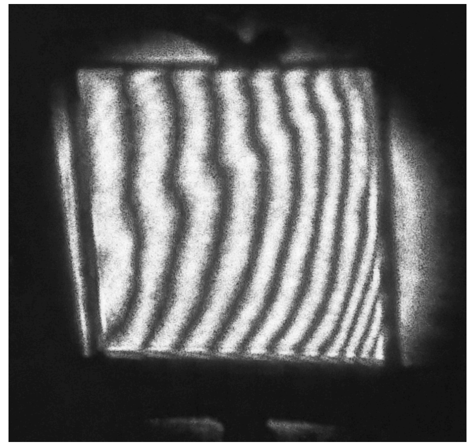
The below diagram shows the laser interferometer we studied in class, with a photograph of the stripes shown to the right. These diagrams are used for questions 4, 5, & 6.





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

A) If neither path is blocked we see stripes because the waves interfere (add and subtract). 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 neither path is blocked we see stripes because the waves interfere (add and subtract). 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 neither path is blocked 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 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.

5) We turn the brightness of the laser down **very** low so that emits one photon of light at a time, and we leave both paths unblocked. In addition we replace the screen with an expensive camera that can detect how hard each photon hits. Which answer accurately describes what we see and why?

A) Because photons move like waves, each photon is smeared across the image. We see stripes as before, but each photon hits the entire detector at once.

B) We see a faint pointillism painting of individual photons hitting the screen. Because the photons are particles they appear randomly across the screen to make a smooth featureless image. The detector measures each photon as hitting with the same strength.

C) We see a faint pointillism painting of individual photons hitting the screen. The photons build up an image of stripes like in the diagram. 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 photons build up an image of stripes like in the diagram, with photons likely to hit near the bright stripes and never hitting in the dark stripes. The detector measures each photon as hitting with the same strength.

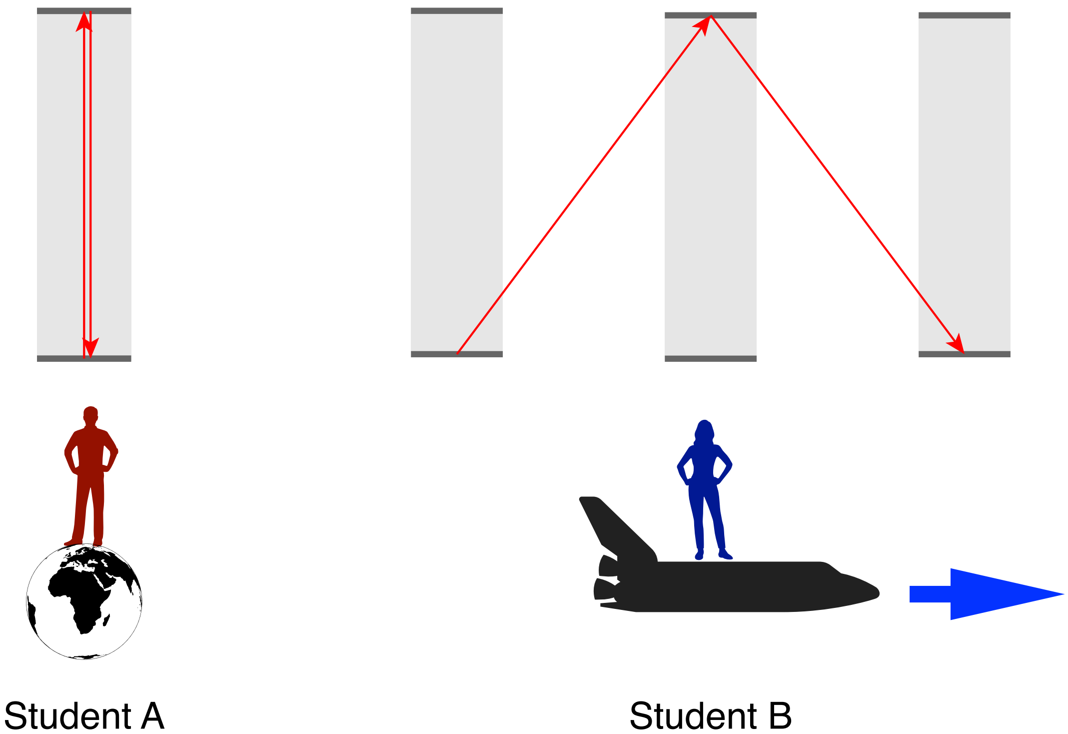
6) We replicate the same setup as in problems 4 & 5, but this time we use neutrons instead of light. Which answer accurately describes what we see and why?

A) Because neutrons are particles, they must travel either the left or right path. So we see the same smooth featureless pattern regardless of whether we block the right path, the left path, or leave both paths unblocked.

B) Because all particles move like waves, we see the same pattern of pointillism stripes as we saw with light.

C) Because all particles move like waves, we see the same pattern of smooth stripes as we saw with light with each neutron smeared across the detector.

D) Because neutrons are particles they will hit like little paintballs: hardest were the stripes are bright and very weakly where the stripes are dark.



7) The diagram above shows two students with light clocks, Student A on earth and Student B on a space ship. Which answer correctly describes the situation?

A) The diagram shows what student B observes. She sees the clock on the earth as going faster than hers because the light has a shorter distance to travel.

B) The diagram shows what student B observes. She sees light and time as moving slowly at earth because it has a shorter path to travel.

C) The diagram shows what student A observes. He sees light and time as moving quickly on the space ship because the light has farther to go.

D) The diagram shows what student A observes. He sees time as moving slower on the space ship because the light in her clock has farther to travel.

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Essay Question

Explain how GPS works. Make sure to include both the fundamental physics principles and the technique. You will be graded on both the accuracy and clarity of your answer. Bonus for describing additional applications of GPS.