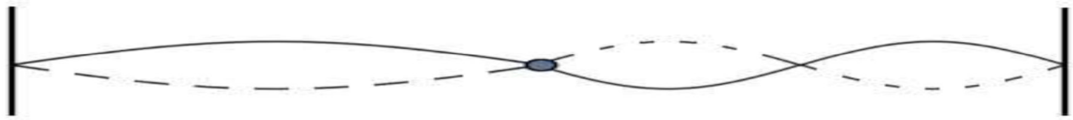


Question 18: Two strings of equal length (but different density) are joined together and set to vibrate in a standing wave. If the wave is as shown in the figure above, what is the ratio of the linear density of the string on the left to the linear density of the string on the right (μ_L/μ_R)?

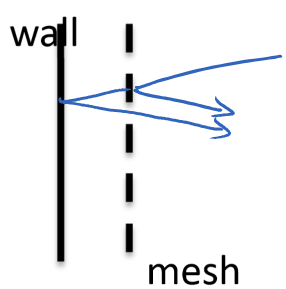
A) 1/4
B) 1/2
C) 1
D) 2
E) 4

same frequency for all parts
double wavelength on left
$\Rightarrow v = \lambda \cdot f$ double on left

same tension τ throughout.

$v = \sqrt{\tau/\mu}$ $\therefore$ need $\mu_{LEFT} = \frac{1}{4}\mu_{RIGHT}$

Question 20: In an effort to control the noise in the Science One study room, James suggests that a wire mesh be installed on the walls to reduce the reflected noise. Some portion of the sound wave will be reflected off it, while the rest will pass through and get reflected off the wall. If James particularly wants to eliminate high-pitched giggling noises whose sound waves have wavelength 0.2m, how far should James install the mesh from the wall? (note: there is no phase shift for the reflections from the mesh or wall)



A) 0.05m
B) 0.1m
C) 0.2m
D) 0.4m
E) 0.8m

want path length difference of $\frac{1}{2}\lambda$

So $2d = \frac{1}{2}\lambda$

$d = \frac{1}{4}\lambda = 0.05m$

Question 21: In a double-slit experiment, laser light is shone through a pair of slits, and a pattern of light and dark spots is observed on a screen. In which of the following situations will the spacing between the spots be the same as it was originally?

A) Laser light with twice the wavelength is used, and distance between the slits is halved.
B) Light with twice the frequency is used, and the distance between the slits is doubled.
C) Laser light with twice the wavelength is used, and distance between the slits is doubled.
D) Laser light with twice the amplitude is used, and the distance between the slits is doubled.

Pattern depends on λ/d so no change for C.

Question 22: In a double-slit experiment, laser light is shone through a pair of slits, and a pattern of light and dark spots is observed on a screen. If an identical experiment is performed in water, we expect that,

A) The spots would get closer together.
B) The spots would get further apart.
C) The pattern would remain the same.

water: smaller v
(index of refraction > 1)
so smaller wavelength

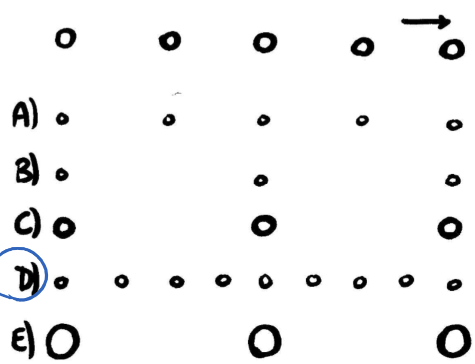
Question 23: A satellite travelling away from Earth emits radio waves uniformly in all directions with some total power P. In order that the amplitude of the radio waves reaching Earth remain the same later when the spacecraft is twice as far from Earth, the total power of the signal must be

A) P
B) $\sqrt{2}$P
C) 2P
D) 4P
E) 8P

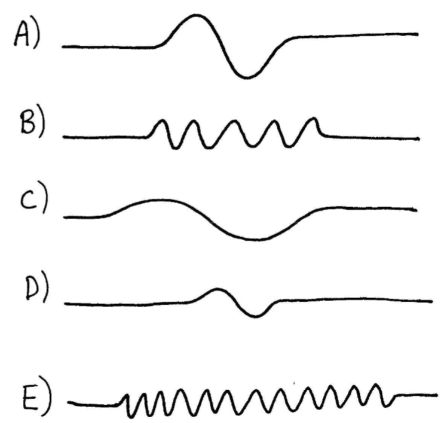
$$\text{Intensity at earth} = \frac{\text{Power}}{4\pi R^2}$$

same amplitude ⇒ same intensity, so if R doubles, need 4x Power

Question 24: The first picture below represents the photons in a beam of UV radiation. If size represents photon energy in the picture, which of the remaining pictures could represent a beam of blue visible light with the same power?



blue light:
smaller frequency
⇓
lower energy photons
Need more photons per second to get same power



Question 26: The five functions above represent the real part of the wavefunctions for electrons moving to the right in a thin wire. After some time, which of these wavepackets will have moved the furthest?

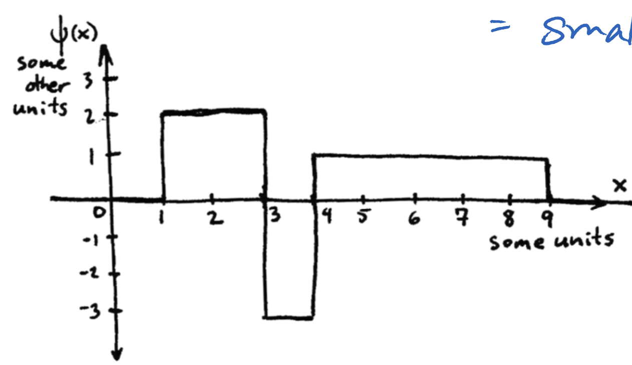
highest momentum ~ shortest wavelength

A) A B) B C) C D) D E) E

Question 27: At this later time, which of the wavefunctions in the previous question will have spread out the most relative to its initial size?

A) A B) B C) C D) D E) E

Biggest spreading: = largest momentum uncertainty = smallest position uncertainty



Question 28: The graph above represents the wavefunction for an electron in a thin wire. In which region is the electron most likely to be found if a measurement of position is performed?

$|\psi|^2$ gives probability density

A) between 1 and 3
B) between 3 and 4
C) between 4 and 9
D) Finding the electron in each of these regions is equally likely.

multiply by length of region to get prob. for that region

Question 29: An electron is bound in a hydrogen atom in a state with some definite energy E. Which of the following is *not* true?

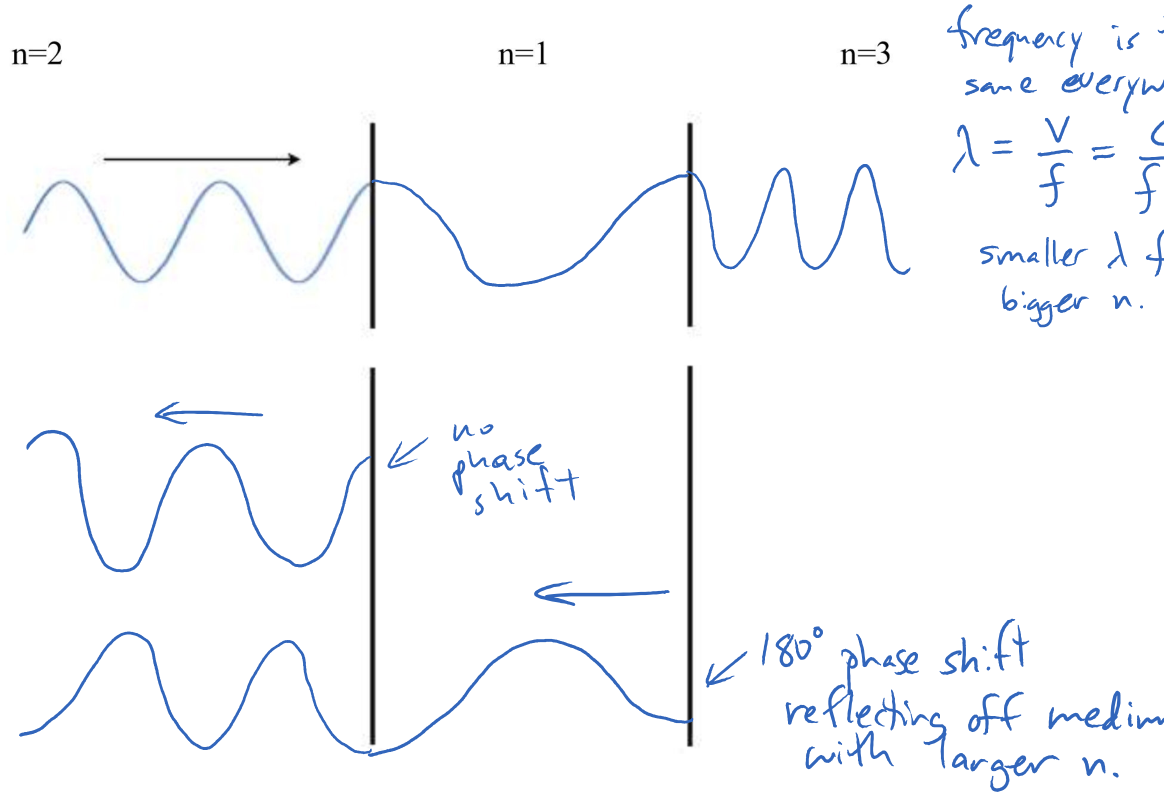
A) There is a minimum possible value for E
B) The electron does not have a definite location
C) The electron does not produce electromagnetic radiation because its velocity is zero
D) The wavefunction for the electron oscillates with a definite frequency

Velocity not zero (it is in some superposition of possible velocities)

Question 23:

Light passes through a material that has two changes in the index of refraction. Draw the transmitted waves on the upper and the reflected waves on the lower part of the figure.

(2 points)



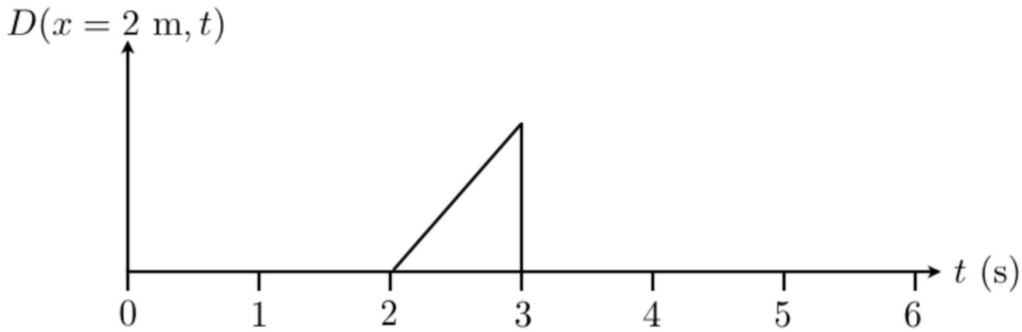
frequency is the same everywhere

$$\lambda = \frac{v}{f} = \frac{c}{f \cdot n}$$

smaller λ for bigger n.

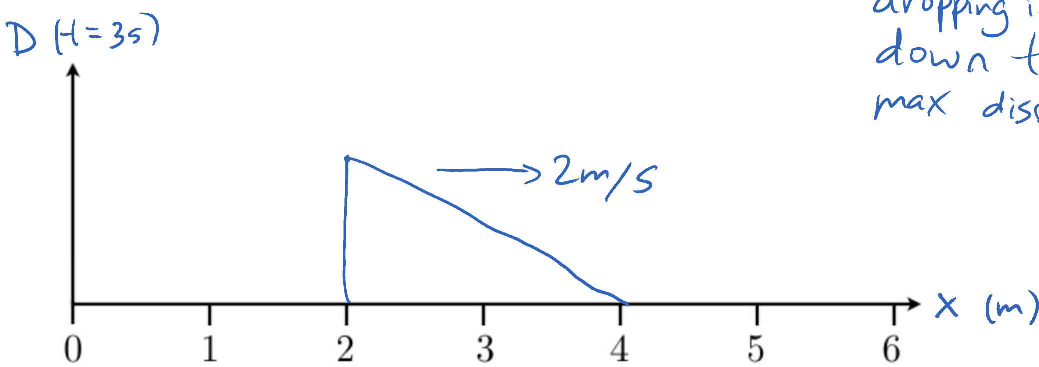
Question 24: Below is a history graph of a wave pulse travelling at 2 m/s to the right.

(2 points)

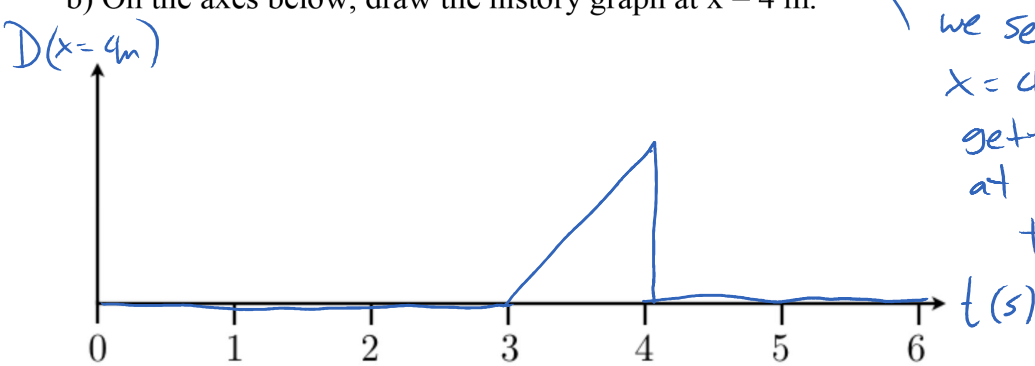


at t=3s, x=2m is dropping instantaneously down to zero from max displacement

a) On the axes below, draw the snapshot graph for t = 3 s.

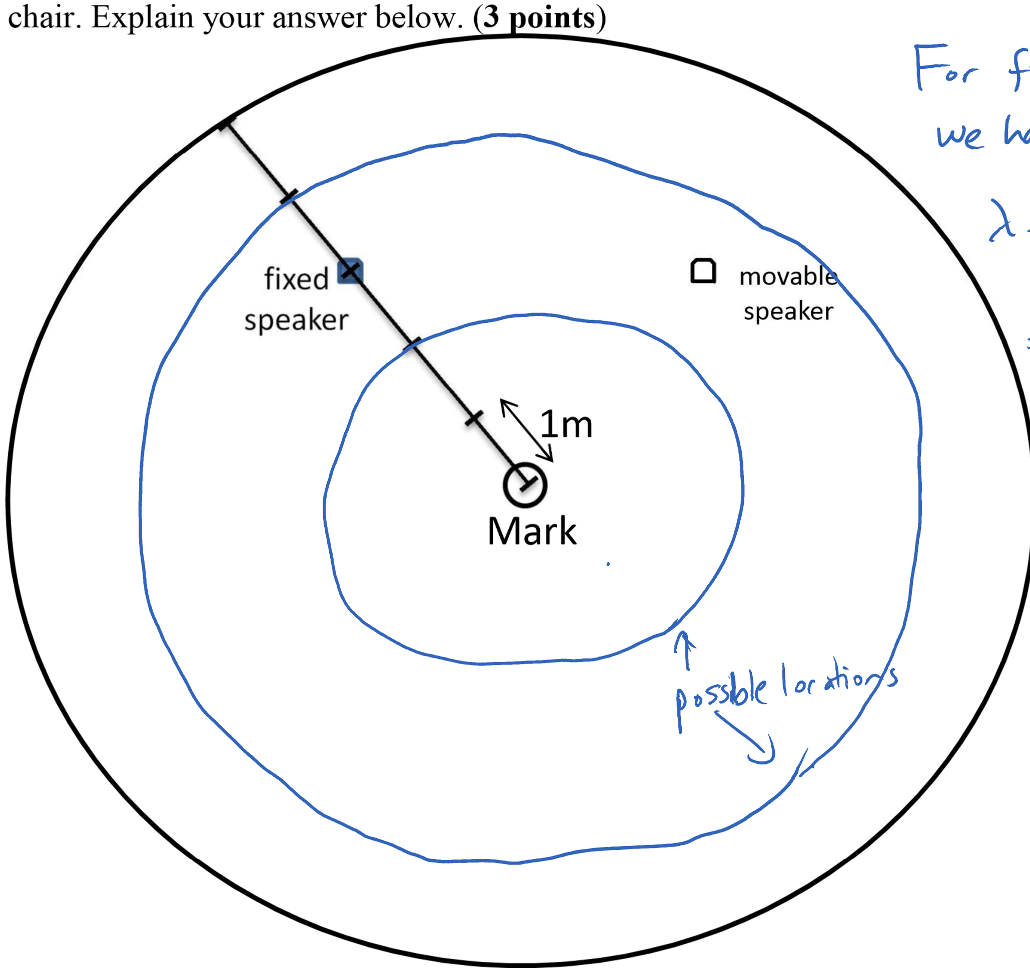


b) On the axes below, draw the history graph at x = 4 m.



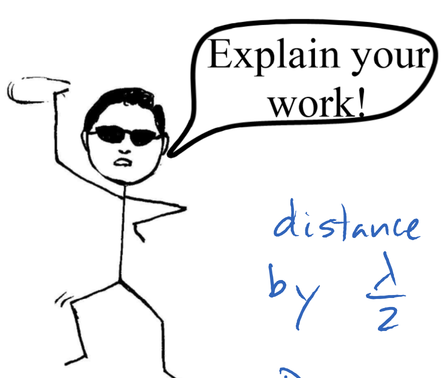
we see that x=4m starts getting dispaced at t=3s. It takes 1s for the pulse to pass

Question 26: Mark sits in the middle of a round room listening to Gangnam Style on repeat. Several days later, he begins to get tired of listening to the song. Unfortunately, there is no way to turn off the music. Fortunately, he finds that only one of the speakers is attached to the ground, and the other one can be moved anywhere he likes. On the picture below, indicate all the places where Mark can move the second speaker so that the most annoying part of the music (which has a frequency of 170Hz) will be as quiet as possible at the location of his chair. Explain your answer below. (**3 points**)



For $f = 170\text{Hz}$, we have:

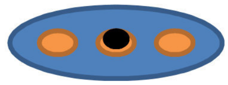
$$\lambda = \frac{v}{f} = \frac{340\text{m/s}}{170\text{Hz}} = 2\text{ m}$$



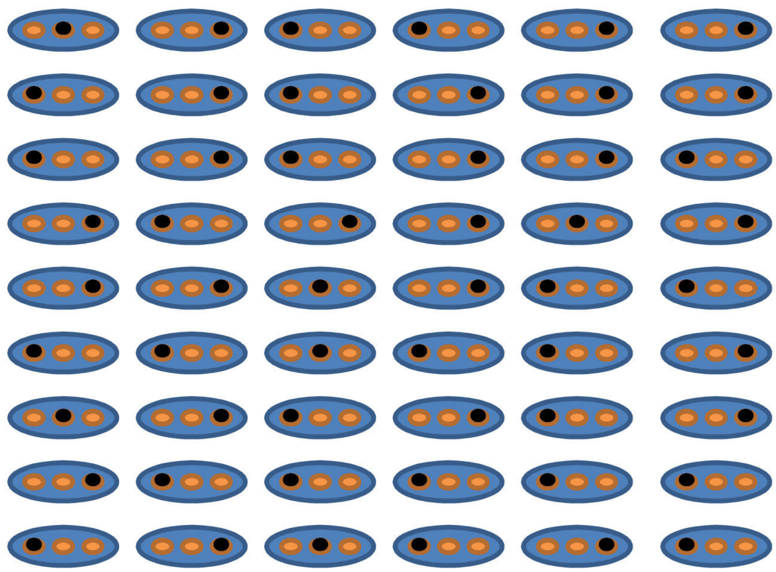
We would like destructive interference at the location of the chair. So we want the path from Mark's chair to the fixed speaker to differ from the path distance from Mark's chair to the movable speaker by $\frac{\lambda}{2}$, $\frac{3\lambda}{2}$, $\frac{5\lambda}{2}$, etc...

$\therefore D_{\text{Mark to Moveable}} - D_{\text{Mark to fixed}} = \pm 1\text{m}, \pm 3\text{m}, \pm 5\text{m} \ldots$

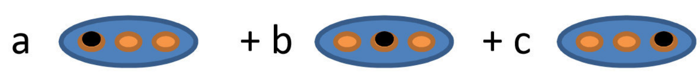
$D_{\text{Mark to Moveable}} = 2\text{m}, 4\text{m}, 0\text{m}, 6\text{m}, 8\text{m}, \text{etc} \ldots$



Question 31: A microscopic quantum device is constructed which can trap an electron in three possible locations on its surface. Experimenters prepare a very large number of these devices, each with a single electron in the middle location. After some time, the position of the electron is measured in each device. The figure below shows a representative sample of the outcomes for these measurements



We can explain the results of the measurements above by saying that before the measurements, each electron was in the same state, a *quantum superposition* that we can represent as:



Explain what this means, describe the significance of the numbers a, b, and c, and suggest values for the numbers a, b, and c that would be consistent with the measurement results above.

A quantum superposition is a state where the electron does not have a definite location. The position eigenstates in the superposition tell us which results we might obtain if we make a measurement of position, with the square of the coefficients a, b, c. telling us the probabilitly that we will obtain the result , , or  respectively. In the measurements above, we have:

 – $24/54 = \frac{4}{9}$

 – $6/54 = \frac{1}{9}$

 – $24/54 = \frac{4}{9}$

Assuming that these fractions are representative of the actual probabilities we could say that $a = \frac{2}{3}$, $b = \frac{1}{3}$, $c = \frac{2}{3}$ would nicely fit the observations.

(However: any nonzero values of a, b, c would be consistent with the measurements, since knowing the probability of something happening does not exactly correspond to how often it happens if we just look at a small set of measurements).