## *Question/Problems*

**1**.Two microwave emitters are sitting side by side, both emitting the same wavelength microwaves. The wavelength of these microwaves is known to be between 2.0 cm and 3.0 cm. As you move a detector around in front of them, you find that when the detector is an equal distance from each emitter, the detector reading is a *minimum*. You also note that when you are 3.75 cm closer to one emitter than the other, the detector reads a *maximum*.

(a) What is the phase relationship between the microwaves coming from the two emitters? Explain how you determined this.

(b) What is the *frequency* of the microwaves coming from the two emitters?

**2**. The first order maximum caused by a double slit illuminated with light of wavelength 645 nm is found at some spot on a screen. The light source is changed to a new wavelength which places its second order ($m$=2) maxima at the same spot where the 645 nm first order maxima used to lie.

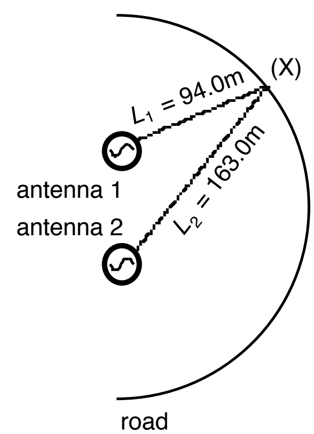
(a) What is the wavelength of the new light source?

(b) Is this wavelength in the visible range?

**3**. Radio station KPHY uses two antennae to transmit its signal at an AM frequency of 1,520 kHz. While driving by on a semi-circular road around these antennae, you notice that there is *only* one location where the signal from both antennae is totally destructive. At this location (X), you are 94.0 m from antenna 1, and 163 m from antenna 2.

(a) Explain your reasoning in how you would know that the radio waves from antenna 1 are not completely in phase (*i.e.,* $\phi_1 \neq \phi_2$) with the radio waves from antenna 2.

(b) Find the difference in the constant phase $\Delta\phi$ (in radians) between antenna 1 and antenna 2.




**4.** Recall that sounds less than 20 Hz in frequency are subsonic; that is, we cannot perceive these frequencies as the subjective experience of pitch. Explain just how it is possible, then, that we were able to detect beat frequencies of *less* than 20 Hz in DL.

**5.** Explain why you are *not* allowed to superpose two waves that have different wave velocities.

**6.** Explain in words that a non-physics student would understand why a light source shining through a double slit of the proper separation causes an alternating pattern of bright and dark lines on the wall.

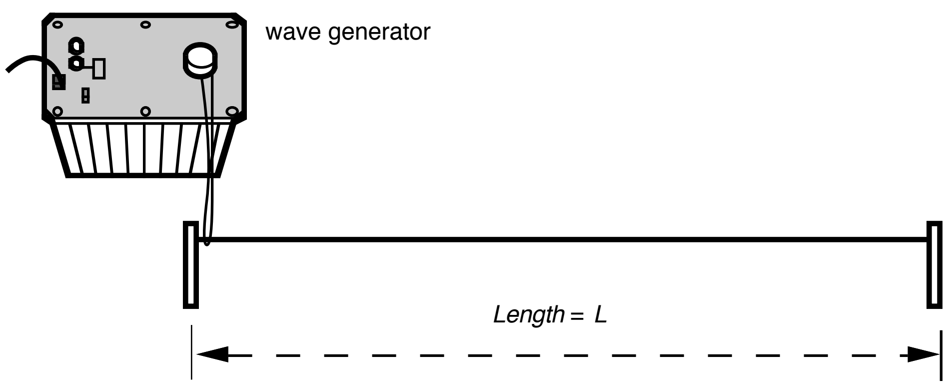
**7**. Microwaves of wavelength $\lambda$ = 1.5 cm are incident on a double slit apparatus with a slit separation distance of 6.0 cm.

(a) What is the separation (in mm) of neighboring interference maxima on a screen 1.0 m away from the slits?

(b) Discuss what parameters could be changes to move the maxima angles farther apart from each other.

**8**. Explain why it is that you sound so much better in the shower when you sing only certain notes. Take a shower and try this out if you not already guilty of this. Calculate the lowest frequency that will sound "nice" in your shower (assuming that it is enclosed on all sides).

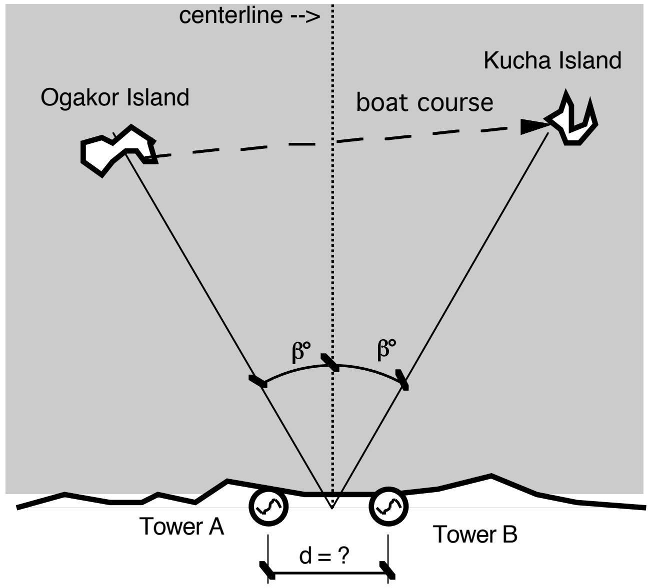
**9**. A Physics 7C student is experimenting with making standing waves on a rope of length $L$ with a wave generator. The student notes that she creates a standing wave with four anti-nodes when the frequency of the wave generator is 160 Hz (i.e. $f_4 = 160 Hz$). Later on in the experiment, the student notes that the frequency of the wave generator is 360 Hz (i.e. $f_9 = 360 Hz$) when a standing wave of nine anti-nodes is created.




(a) If the student were to halve the length of the rope (*i.e.* $L_{new} = \frac{1}{2}L$), which of the previous frequencies (*i.e.* either $f_4$, $f_9$, both, or neither) would still create a standing wave on the rope? Give the number of anti-nodes this (these) standing wave(s) would have.

(b) If the student were to double the length of the rope (*i.e.* $L_{new} = 2L$), which of the previous frequencies (i.e. either $f_4$, $f_9$, both, or neither) would still create a standing wave on the rope? Give the number of anti-nodes this (these) standing wave(s) would have.

**10**. Two independent radio towers (which may or may not be in phase with each other) transmit radio waves with a frequency of 1.5 MHz , *i.e.* $f = 1.5 \times 10^6 Hz$ . The towers transmit these waves to two islands (Ogakor and Kucha) which always receives a constant constructive interference signal. Both of the islands are located at an angle of β with respect to the center line (but on opposite sides of the centerline.)

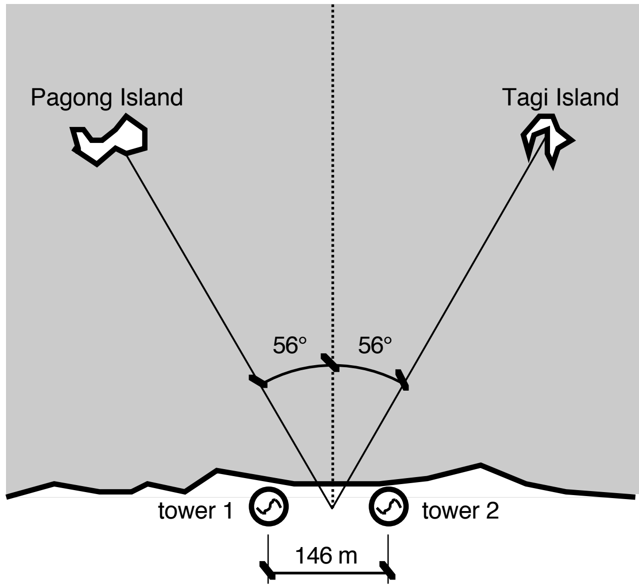



Ogakor Island is 11,843 meters from Tower B and 11,343 meters from Tower A. Kucha Island is 12,512 meters from Tower A and 12,012 meters from Tower B. The distance, *d*, between the two towers is unknown but it is much less than the distances given above. (Radio waves are a type of light waves.)

(a) What is Δϕ (the constant phase difference) between Tower A and Tower B?

(b) A boat goes in a straight line from Ogakor island to Kucha island as shown in the diagram above. How many minima (*i.e.* completely destructive lines) will the boat detect as it goes from Ogakor to Kucha?

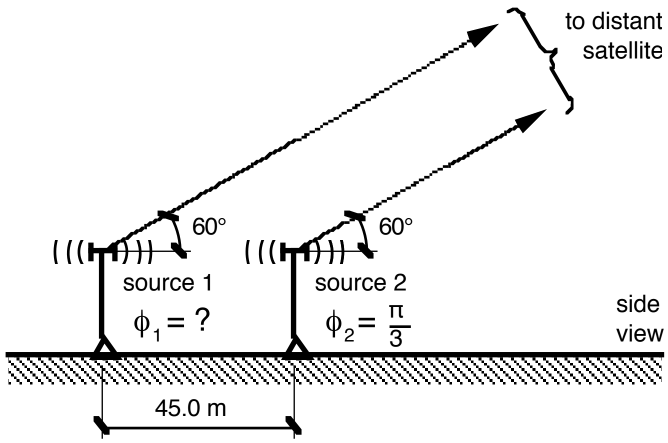
**11.** A radio station transmits from two towers spaced 146 m apart. Each tower emits a radio wave in all directions. As a result, Tagi Island receives a radio transmission of constant maximal amplitude, and Pagong Island continuously receives absolutely no radio transmission. The map at right is not to scale, but Tagi Island and Pagong Island are both very far away from the radio towers. (Radio waves are a type of light waves.)




(a) Explain in words and/or equations (i) what must be happening at Tagi Island and at Pagong Island, and (ii) how the different quantities in the wave equations for each tower compare relative to each other (*e.g.,* same as/different than) for this to happen. Use a phase chart to organize your thinking and summarize your results.

(b) Consider now a difference situation where the two radio towers have the same constant phase and have the same wavelength (which may or may not necessarily have been the case before in (a)). What is the longest possible wavelength that they should both transmit such that both Tagi Island and Pagong Island receives a radio transmission of constant maximal amplitude?

**18**. Two sources are spaced a horizontal distance of 45.0 m apart, and both emit l = 30.0 m radio waves in all directions. A distant satellite at an angle of 60° from the horizontal receives a constructive interference signal from these two sources. The drawing is not to scale.




(a) Determine the smallest positive value for the constant phase $\phi_1$ (in radians) of source 1, if the constant phase $\phi_2$ of source 2 is $+\pi/3$.

(b) Now consider the case where both radio sources have exactly the same constant phase. Determine whether the satellite will now be able to detect a radio signal or not.

I. The satellite will be able to detect a radio signal from source 1 and source 2.

II. The satellite will be *not* able to detect any radio signal from source 1 and source 2.

## *Q/P Comments*

**1.** (a) Draw a diagram. If the waves are the same frequency and producing a destructive interference when there is no path length difference for the two sources, are the two sources in phase (*i.e.,* their constant phases are the same) with each other? What must be the difference in their constant phases?

(b) From what we are given in this problem, you will first need to find the wavelength of the waves before you can find the frequency. You know that the wavelength is between 2.0 cm and 3.0 cm. And you know when the path length difference is 3.75 cm, you find a maximum. What are the conditions for finding a maxima for *this* arrangement? The path length difference to a maxima must be equal to a half-wavelength ± a whole wavelength multiple. (Why?) Of the possible wavelengths, only 2.5 cm fits between 2.0 cm and 3.0 cm.

**2.** (a) Note that in either of the two cases ((1) and (2)), the spacing $d$, and the angle θ are the same. This means that $d\sin\theta$ , and thus the path length difference in absolute terms (i.e. millimeters) is the same. The only differences are the wavelengths $\lambda_1$ and $\lambda_2$, and the maxima orders $m_1$ and $m_2$, which means the path length difference in terms of wavelengths is not the same for both light sources. We can solve two simultaneous constructive interference equations for the second wavelength:

$$\left.\begin{aligned} m_1\lambda_1 &= d\sin\theta \\ m_2\lambda_2 &= d\sin\theta \end{aligned}\right\} \rightarrow m_1\lambda_1 = m_2\lambda_2 \rightarrow \lambda_2 = \frac{m_1\lambda_1}{m_2} = \frac{(1)(645\text{ nm})}{(2)} = 323\text{ nm}.$$

(b) Use $c = \lambda f$ .

**3.** (a) Calculate the path length difference for the two sources. Is this what you would expect for destructive interference at point (X)?

(b) What should the total phase difference ΔΦ be at point (X)? Fill out a phase chart to solve for the difference in constant phases Δϕ.

**4.** You can't hear fluctuations in pressure (*i.e.,* pitch) that are less than 20 Hz in frequency, but what about *modulations in amplitudes (intensities, loudness)?* Turn your stereo volume knob up and down and up and down with a frequency of say, 1 Hz or 2 Hz. Can your roommates tell that you're messing with their ears?

**5.** Now just how would you get two different wave velocities? By the way, can you superpose waves with two different wavelengths? Two different frequencies?

**6**. Sit your non-physics colleague down over a cup of coffee for this one, as there are a lot of important ideas to cover. You should mention how light (or any periodic wave) can interfere constructively or destructively; how two light sources will interfere at a given point depending on the difference between their path lengths; and how two narrow slits can approximate two ideal light sources.

**7**. (a) Since the sources are in phase, the angle $\theta = 0°$ is a maxima ($m = 0$). So we need to locate the neighboring $m = 1$ maxima using $m\lambda = d\sin\theta$, and this maxima will be at 14.48° away from the $\theta$=0° center line. Next, we need to do a bit of trigonometry to find the distance between these maxima on the screen. *(Answer: 258 mm.)*

(b) To increase the spacing between these maxima on the screen, we could always move the screen further away from the slits. Looking at the constructive interference equation, we can also increase it by increasing $\theta$, which can be done by either decreasing $d$, or increasing $\lambda$.

**8**. These "good-sounding-shower-notes" are wave frequencies that interfere constructively in your shower. However, these frequencies may not be on-key with any known musical scale (*cf.* the piano key frequencies in the following Appendix section), as your roommates may inform you after your shower.

**9**.The important point to this problem is to remember that for standing waves on a rope there must be nodes at the endpoints. Also recall the ubiquitous $v=\lambda f$

**10**. (a) Fill out a phase chart.

(b) Recall the pattern of maxima and minima that you have seen for 2D interference. Drawing a picture of the maxima and minima lines might help out to see what is going on. *(Answer: 5 minima.)*

**11**. Recall that the only things that can cause interference are either a path length difference, a frequency difference, or a constant phase difference. Keep careful track of your signs!

**12**. Fill out a phase chart. For constructive interference, you want $\Delta\Phi = \pm$even $\pi$. Also, you can approximate the path length distance with $\Delta x = d\sin 30°$. Don't forget that all angles are measured with respect to the centerline. In order for the satellite not to detect any signal it must be in completely destructive interference.

*Piano Key Frequencies*