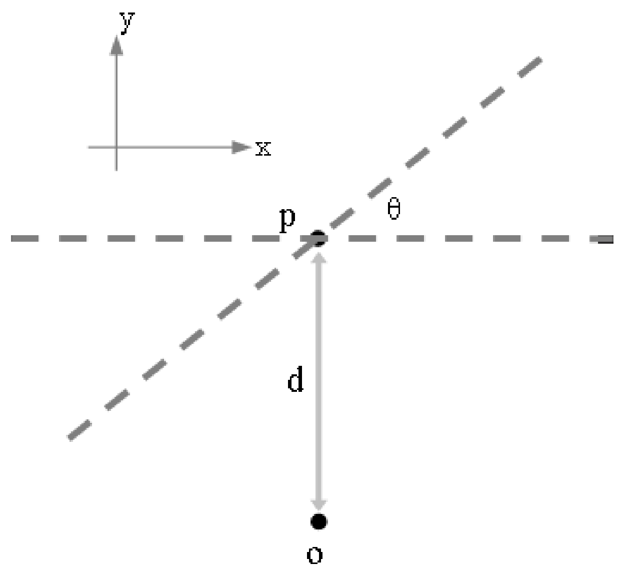
Question 1.

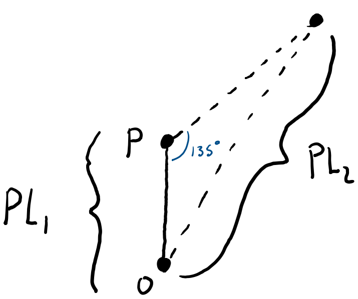
Two 100-m (λ), in-phase spherical wave sources are located at point ***p*** in the figure. An observer is located at point ***o***, a distance of 10 m in the positive ***y***-direction away from point ***p***. One of the wave sources moves at 2 m/s along a line 45° from the ***x*** axis.



(a) How long will it be before the observer detects another maximum. There may be more than one correct answer.

Use *Order of Magnitude* sensemaking in conjunction with *Related Quantities* sensemaking by answering the following prompts:

(b) Do you expect the wavelength to be much larger, about the same, or much smaller than the distance traveled by the moving source? Explain. How long would it take the moving source to travel the distance of one wavelength? Given your answers, explain why you think your answer is reasonable (or isn't!).



$PL_1 = 10\,m$

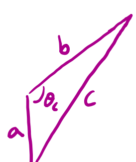
$PL_2 = ?$

maximum ⇒ constructive

⇒ $PLD = 1\lambda = 100m$

$PLD = PL_2 - PL_1 = 100m$

⇒ $PL_2 = 110\,m$



law of cosines

$c^2 = a^2 + b^2 - 2ab\cos\theta_c$

$110^2 = 10^2 + b^2 - 2(10)\,b\,\cos(135°)$

$0 = b^2 + 14.1\,b - 12000$

⇒ $b = 102.7m$ or $-116.8m$

$\Delta t = \frac{b}{2\,m/s} = 51.4$ sec or 58.4 sec

if source travels direction instead of

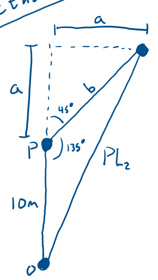
(b) because we are looking for the first maximum, and we know $PLD = m\lambda$, we are looking for the $m=1$ case.

⇒ $PLD = \lambda = 100$ meters

⇒ we should expect the source to travel on the order (within a factor of 10) of 100 meters.

We find that it travels either 103m or 117m ⇒ our answers are believable!

alternate method



pythagorean thm.

$a^2 + a^2 = b^2$

$a = \frac{b}{\sqrt{2}}$

pyth. thm.

$(a+10)^2 + a^2 = (PL_2)^2$

$a^2 + 20a + 100 + a^2 = (110m)^2$

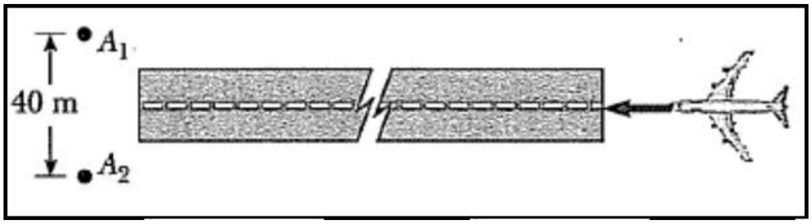
$2a^2 + 20a - 12000 = 0$

$b^2 + \frac{20}{\sqrt{2}}b - 12000 = 0$

Same as above from here!

Question 2.

Young's double-slit experiment underlies the instrument landing system used to guide aircraft to safe landings when the visibility is poor. Although real systems are more complicated than the example described here, they operate on the same principles. A pilot is trying to align her plane with a runway as suggest in the figure. Two radio antennas A_1 and A_2, separated by 40.0 m, are positioned adjacent to the runway. The antennas broadcast single frequency, 30.0 MHz, coherent radio waves.



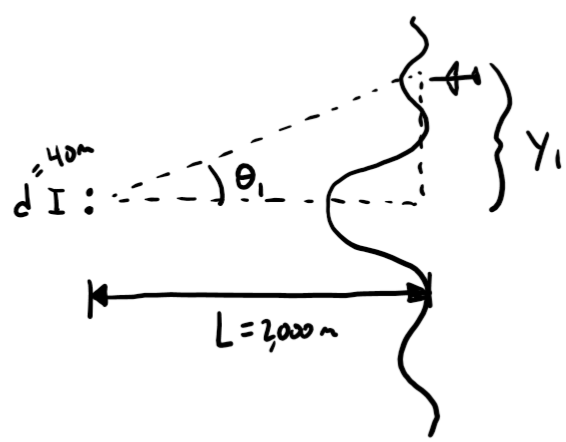
(a) Find the wavelength of the waves. The pilot "locks onto" the strong signal radiated along an interference maximum and steers the plane to keep the received signal strong. If she detects the central maximum, the plane will have the right heading to land when it reaches the runway.

(b) Suppose instead that the plane is flying along the first side maximum, one maxima from the central. How far to the side of the runway centerline is the plane when it is 2.00 km from the antennas?

(c) It is possible to tell the pilot she is on the wrong maximum by sending out two signals from each antenna and equipping the aircraft with a two-channel receiver. The ratio of the two frequencies must not be the ratio of small integers (such as 3/4). Explain how this two-frequency system would work, and why it would not necessarily work if the frequencies were related by an integer ratio.

(a) $c = f\lambda$ $\lambda = \frac{3\times10^8}{30\times10^6} = \boxed{10\,m}$

(b)



$m\lambda = d \sin\theta$

$\Rightarrow (1)\lambda = d \sin\theta_1$

$\Rightarrow \theta_1 = \sin^{-1}\left(\frac{\lambda}{d}\right) = 14.5°$

$\triangle \Rightarrow \tan\theta_1 = \frac{y_1}{L}$

$\Rightarrow y_1 = L\tan\theta_1 = 516.4\,m$

(c) For such ratios, the 2nd maximum of one interference pattern may coincide with the 3rd (or similar) fringe of the other pattern, leading the pilot to think they are seeing the central fringe of both.