

# Science You Can Use

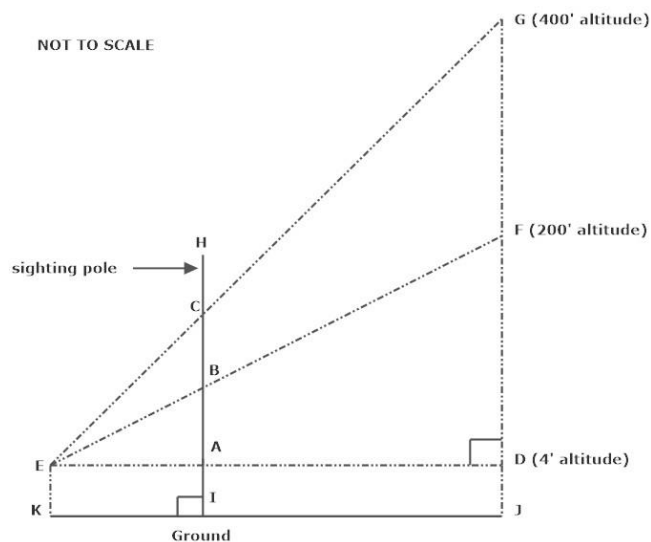
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My wife volunteered to determine whether contestants in an air race pass over a timing point at an altitude of 200 to 400 feet above ground. The altitude of the ground above sea level at the observer's position and at the timing point is the same. The observer is on the ground, 400 feet (measured along the ground) from the timing line. Laser- and radar-based distance-measuring equipment are not allowed be used to measure the altitude. Any sighting-assistive device must be transportable inside a car and light enough that one person can carry it. No more than two people can be required to install it. She asked me how to solve this problem.

A calibrated "sighting pole" placed between the observer and the timing line can solve this problem. The approach can also be used to determine the height of many other objects (e.g., trees, houses, antenna towers) at a distance. Here are some details.

In the following, "altitude" will mean "altitude above local ground".

Figure 1 illustrates the geometry of the problem. E is the location of the observer's eye. Segments EK, IA, and DF are each 4 feet long. Angle EDG is a right angle. The timing line runs at 90 degrees to the plane of the paper through J (the "timing point"). The length of leg ED (the distance between the observer's eye and a point 4' above the timing line) is equal to the length of leg DG. DG is an imaginary line running directly above, and at a right angle to, the timing line. ED is parallel to the ground. Because GD and ED have the same length and triangle GDE is a right triangle, angle GED is 45 degrees.



**Figure 1. Sighting pole diagram.**

*Constructing a sighting pole.* We built a sighting pole from three 5-foot sections of 1.5” Schedule 40 PVC pipe. We joined the sections of the pipe with PVC coupling sleeves. On the bottom of the pole, we attached a PVC adapter for a 1.5-inch threaded, galvanized iron floor flange, and attached the floor flange to the other end of the adapter. This created a rudimentary “foot” for the pole.

We positioned the pole so that EA was 8 feet. We then ran a level string along EA. With the help of an inexpensive protractor, we ran another string from E to the pole so that the angle between EA and EC was 45 degrees; we marked the “C” intersection with hot pink duct tape. This mark corresponds to 400 feet above the timing line. Again, using a protractor, we ran a string from E to B so that the string was 30 degrees with respect to the string along EA and marked the “B” with the same duct tape. This mark corresponds to 200 feet above the timing line.

We guyed the pole with three 30-foot lengths of parachute cord, with each piece separated from its neighbors by about 120 degrees. We fastened the guys to the pole just above the top of the topmost pipe sleeve using non-slip knots. We drove three 9” nails through the holes in the floor flange into the ground. We anchored the other end of the guy lines with tent stakes.

We did not glue any connections among the parts of this assembly.

*Testing.* To assess whether our sighting pole met our observational needs, we positioned an observer at E in the configuration described above. A pilot then made four flights over the timing point: one pass, at 200 feet altitude; two passes, between 200- and 400-foot altitude; one pass, at 400 feet altitude. The ground observer recorded where the plane passed behind the sighting pole. The pilot recorded the altitude reported by the plane’s onboard GPS. The ground observer’s, and the pilot’s, records were then compared. The altitude measured at the 200-, and 400-foot points by the sighting pole method was within 5% of the altitude measured by the GPS method. The altitudes of the flights strictly between 200 and 400 feet flew between the 200-, and 400-foot markers on the sighting pole. That’s good enough for this application.

*Some sensitivities of the approach.* The approach described above evidently works well enough for the use described. It will not work in settings when the plane is too small to be seen by the unaided eye, when the separation of G and F is too small to be seen by the unaided eye, when the plane is moving so fast that humans cannot judge when it crosses the timing line, or when the plane is in the dark, to name a few. If the length of ED is not 400 feet and/or the length of EA is not 8 feet, then location of C and B on HI will be different than they are in the configuration described above.

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*Jack Horner is a systems engineer. Thanks to Clancey Maloney for suggesting the sighting-pole solution.*