Measuring the Flight Speed of Fire Bombers from Photos: An In-Class Exercise in Introductory Kinematics

Greg W. Lowe and Eric Ayars, California State University, Chico

In the western half of the United States, fire bombers are not an uncommon sight. During the "fire season," which can extend from June through November, these specially modified aircraft are used to drop fire retardant chemicals or water on wildfires. It can be an entertaining and instructive classroom exercise to use pictures of these planes in action to calculate the speed of the plane during a drop run.

In Fig. 1, one can see a Grumman S-2A Tracker dropping Phos-Chek retardant ahead of a wildfire. The approximately parabolic trajectory of the retardant is clearly visible in the photo,[1] which can be provided to the students or projected at the front of the class. Using the length of the plane as a reference, and the assumption that the retardant is approximately in free fall, one can reasonably estimate the speed of the plane from this photo.

Measuring directly on the photo in units of "plane lengths" (L), we find that the retardant has fallen a distance of approximately $y \approx 1.1L$. The length of the S-2A is 13.3 m,[2] so $y \approx$ 15 m. We can then use the equations for constant-acceleration motion to find the time the retardant has been falling:

$$y = y_i + v_i t + \frac{1}{2} g t^2 \Rightarrow t = \sqrt{\frac{2(y - y_i)}{g}} \approx 1.7 \text{ s}, \qquad (1)$$

where the initial vertical velocity v_i and vertical displacement y_i are assumed to be zero. The plane has traveled approximately $x = 6.7L$ (or 89 m) in this time, so the speed of the plane is

$$v = \frac{x}{t} \approx 52 \text{ m/s}. \qquad (2)$$

This is of course a very rough estimate! A close examination of Fig. 1 shows that the curve of retardant is not actually parabolic: it becomes approximately linear on the left side as the retardant approaches terminal velocity. One can also see the effects of air resistance in the photo from the leading edge of the falling retardant. In the absence of air resistance, the retardant would remain directly below the aircraft at all times, but one can see that the leading edge of the retardant is not a straight vertical line. In addition, it is not certain that the path of the airplane is entirely in the plane of the picture, or that the speed of the airplane is constant. A conversation with the pilot of this particular aircraft, however, revealed that her ideal approach speed is 120 knots, or 62 m/s.

Depending on the needs and interests of your class, this can be used as a starting point for further discussion. For example: how far should the retardant have dropped at the halfway point, $x = 3.3L$? Is this estimate supported by the photo? Do the visible effects of air resistance on the falling retardant make our speed estimate lower or higher than the actual airplane speed? Did the drop begin somewhere to the right of this photo, and how would that affect the accuracy of our speed estimate? What is the uncertainty in our estimate of v?

Fig. 1. Grumman S-2A Tracker drops retardant ahead of a wildfire.

References

1. Photo courtesy of Ray Trussell. This photo is available for classroom use at http://phys.csuchico.edu/ayars/drop1.jpg.
2. John W. R. Taylor, *Jane's All the World's Aircraft*, 1968-69 (McGraw-Hill, New York, 1969), p.283.

Greg W. Lowe *currently teaches physics at The Bishop's School in La Jolla, CA. He taught in the physics and math departments while working on his MS in hydrology at California State University, Chico.*

Eric Ayars *is a physics professor at California State University, Chico, where he works closely with undergraduates on any interesting research projects that happen to come along.*
ayars@mailaps.org

 DOI: 10.1119/1.3293657