

## Terminal Velocity Calculations of a Smartphone

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For falling objects, there are several ways we can calculate the speed at which they will hit the ground. The most definitive is to find the terminal velocity of the item in question, which is the absolute fastest an object can fall in a certain atmosphere, based on the gravitational acceleration, density of the medium the object is falling in, mass, surface area, and coefficient of drag.

The terminal velocity equation states that:

$$V_t = \sqrt{\frac{2mg}{\rho Ac_d}}$$

Where  $V_t$  is the terminal velocity,  $m$  is the mass,  $g$  is the gravitation acceleration, which is on earth is approximated as 9.81 m/s or 32.2 ft/s,  $\rho$  is the density of the medium, in this case, air,  $A$  is the surface area, and  $c_d$  is the drag coefficient.

For the UMi London smartphone, the mass is given as 0.160 kg, with surface area of (4.52 x 2.82) in<sup>2</sup>, assuming maximum air resistance from the smartphone falling on the largest, 2D plane.

Using standard atmospheric charts, we can find that the density of air at ground level, at STP (standard temperature and pressure) conditions is 1.225(10<sup>-1</sup>) kg/m<sup>3</sup>. Since atmospheric tables are typically designed for calculations involving aircraft, it's difficult to find tabulation for 100 feet above sea level, so for the purposes of these calculations I've approximated the air at 100 feet above ground to have roughly the same density at ground level.

Similarly, barring access to a UMi London smartphone and a wind tunnel, it's difficult to accurately assess the coefficient of drag. Therefore, I've used already tabulated drag coefficients, ranging from 1.28–2.05 for a flat plane, perpendicular to a flow to approximate drag forces on the falling phone.

Using the above information, and converting some units for ease of calculation, we find that:

$$V_t = \sqrt{\frac{2 * 0.160\text{kg} * 9.81\text{m/s}^2}{12.25(10^{-1})\text{kg/m}^3 * 0.008223\text{m}^2 * 1.28}} = 49.24\text{m/s} = 161.876\text{ft/s} = 110.37\text{mph}$$

The above formulation is the absolute fastest a UMi London smartphone would fall, assuming the best aerodynamic properties and least amount of drag. With maximum

drag, the UMi London would only hit speeds of 38.98 feet per second, or 26.57 miles per hour.

However, the UMi phone in question was dropped from 100 feet. Is that really enough time and distance reach terminal velocity?

Using a much roughly approximation of velocity for a dropped object:

$$V_f, \text{approx} = \sqrt{2gh}$$

And plugging in our height,  $h = 100 \text{ feet}$ , gives us:

$$\begin{aligned} V_f, \text{approx} &= \sqrt{2 * 32.2 \text{ft/s} * 100 \text{ft}} \\ &= 80.24 \text{ ft/s} = 54.709 \text{ mph} \end{aligned}$$

Which is clearly a much slower speed then our 110.37 mph estimate, even without air resistance. Factoring in air resistance at the 100 foot height would give us approximately 60 ft/s (40 mph) as a good estimate of the actual speed the phone was traveling at when impact occurred.

In any event, whether the fastest speed of 110.37 miles per hour, or the slowest 26.57 mph, the UMi London (and probably most other smartphones) unfortunately did shatter when hitting the ground.