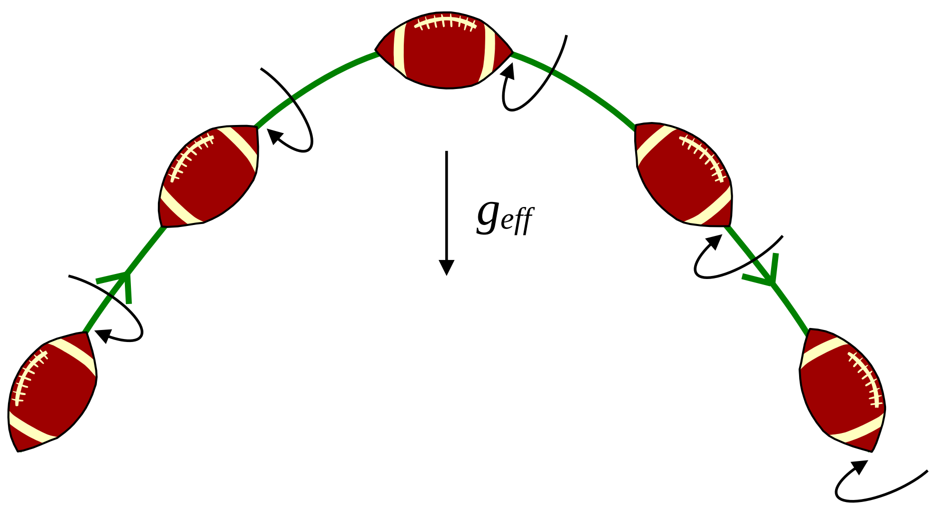
Can a football fly farther if it is filled with helium?

When a football is thrown it is given spin about its axis. This creates gyroscopic stability which enables the football to keep its symmetric (long) axis aligned with its flight trajectory, without tumbling end over end when in flight. The spin imparts a gyroscopic response to the aerodynamic forces acting on the football, which results in the football long axis aligning itself with the flight trajectory (as shown below). The physics necessary to describe this is a combination of gyroscopic analysis and aerodynamic force analysis due to drag and (potentially) the Magnus effect. This is quite complicated and will not be discussed here. However, there is a lot of literature available online on gyroscope physics, as related to projectile spin and gyroscopic stability, if one wishes to study this topic further.



The fact that the football keeps its long axis aligned with its flight trajectory helps make this problem more solvable. This is because the drag force equation, used in the solution, has a constant projected frontal area as well as having a reasonably constant drag coefficient, as a result. This is directly a result of the alignment of the long axis of the football with its flight trajectory.

To start off, consider the general equation for the drag force acting on a body:

$$D = \frac{1}{2} C \rho A v^2$$

Where:

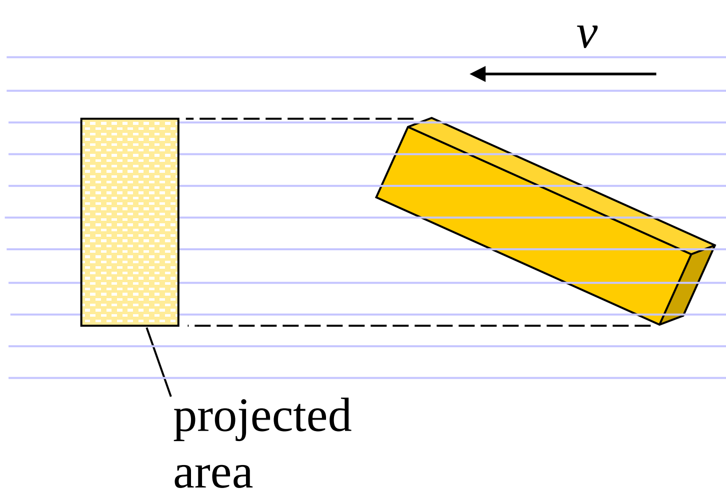
D is the drag force acting on the body

C is the drag coefficient, which can vary along with the speed of the body. For a football this value is about 0.05 (reference: http://users.df.uba.ar/sgil/physics_paper_doc/papers_phys/fluids/drag_football.pdf)

ρ is the density of the fluid through which the body is moving. In this case, the fluid is air so ρ = 1.2 kg/m^3

v is the speed of the body relative to the fluid

A is the projected cross-sectional area of the body perpendicular to the flow direction (that is, perpendicular to *v*). This is illustrated in the example figure below. For a football in flight $A = \pi r^2$, where r = 0.085 m is the radius of the football at the mid point. So A = 0.023 m^2.



The above variables stay the same whether the football is filled with air or helium.

The two variables which depend on whether the football is filled with air or helium are mass and effective gravity. In both cases the football is filled to the same pressure.

The mass of the football will vary depending on if it's filled with air or helium, since they have different densities (helium has a lower density). If a football is filled with air it will typically have a mass of about 410 grams. If it is filled with helium it will weigh about 7 grams less (reference: http://www.discovery.com/tv-shows/mythbusters/mythbusters-database/football-helium-fly-farther). So it would have a mass of 403 grams.

The effective gravity takes into account the buoyant force acting on an object. Air exerts a buoyant force on objects but its effect is usually negligible in projectile motion calculations. To calculate effective gravity we need to know the volume of a football, which is 0.0042 m^3 (reference: http://www.csus.edu/indiv/o/oldenburgj/ENGR1A/NFLFootballWtCalc.pdf).

The equation for calculating effective gravity is

$$g_{eff} = g - \frac{\rho V g}{m}$$

Where:

g_{eff} is the effective gravity

g is the acceleration due to gravity, which is 9.8 m/s^2

V is the volume of the football, which is 0.0042 m^3

ρ is the density of air which is 1.2 kg/m^3

m is the mass of the football (0.41 kg for an air filled football and 0.403 kg for a helium filled football)

For an air filled football the effective gravity is g_{eff} = 9.68 m/s^2. For a helium filled football the effective gravity is g_{eff} = 9.68 m/s^2. There is negligible difference.

Since this is a projectile motion problem we need to know the initial velocity of the football in the horizontal and vertical direction. A football in professional competition is typically thrown at about 27 m/s. It can also be thrown at various launch angles. So for the sake of argument let's test out two launch angles, say 20° and 45° above the horizontal. For the 20° launch angle the horizontal velocity is 27cos20 = 25.4 m/s, and the vertical velocity is 27sin20 = 9.2 m/s. For the 45° launch angle the horizontal velocity is 27cos45 = 19.1 m/s, and the vertical velocity is 27sin45 = 19.1 m/s.

Lastly, we shall ignore the Magnus effect due to the spinning of the ball. This is likely an unimportant effect anyway since the equation for Magnus force is independent of whether the football is filled with air or helium.

To solve this problem we need to use a suitable projectile motion simulator program, such as the one described on http://www.real-world-physics-problems.com/projectile-motion-simulator.html.

Inputting the above values into the simulator we find that an air filled football flies a (horizontal) distance of 45.8 m when launched at 20°, and a distance of 68.7 m when launched at 45°. A helium filled football flies a distance of 45.7 m when launched at 20°, and a distance of 68.6 m when launched at 45°. The difference is clearly negligible, so it makes no difference whether the football is filled with air or helium. This is what the Mythbusters concluded.