Exercise. You are a baseball pitcher and you want to throw a ball from your position to a position 18m away and 1m below your throwing position. How fast should you throw the ball and at what angle with the horizontal?

Note. There are lots of ways that you can throw a ball to the catcher (even disregarding spins), so this problem is under-determined.

(a) Write the differential equation for the position of the ball $\vec{r}$ and the initial conditions.

(b) Write the condition that the ball should reach the catcher at a time $T$. How many equations and how many unknowns are there? Use this to explain why the problem is under-determined.

(c) Fastball. Assume that the pitcher throws the ball horizontally: at an angle $= 0$.
How fast should he throw the ball (initial speed)? And how much time will it take for the ball to reach the catcher?

(d) Home run. Assume that pitcher throws the ball at a $45^\circ = \frac{\pi}{4}$ angle.
How fast should he throw the ball (initial speed)? And how much time will it take for the ball to reach the catcher?

(e) Impossible Throw. Assume that pitcher throws the ball at a $-45^\circ = -\frac{\pi}{4}$ angle.
Show that, without allowing for bounces, it is impossible for the ball to reach the catcher.
(f) **Bouncy Throw (Difficult).** Assume that pitcher throws the ball at a \(-45^\circ = -\frac{\pi}{4}\) angle.
Assume that when the ball bounces, it loses 25% of its speed. How fast should the pitcher throw the ball so that it would reach the catcher with exactly one bounce?

**Extra question.** What is the minimum possible angle (without breaking the speed of light)?