

11.11 How Fielders Catch

WORKSHEET

The question

A fielder, who is perfectly placed to catch a ball struck by the batsman in a game of cricket, watches the ball in flight. Assuming that the ball is struck at the fielder's eye level and is caught just in front of her eye, show that $\frac{d}{dt}(\tan \theta)$ is constant, where θ is the angle between the horizontal and the fielder's line of sight.

In order to catch the next ball, which is also struck towards her but at a different velocity, the fielder runs at constant speed v towards the batsman. Assuming that the ground is horizontal, show that the fielder should choose v so that $\frac{d}{dt}(\tan \theta)$ remains constant.

Hints

Try the question on your own first. If you get stuck, read the hints *one at a time*, and go back to the question after each one. Hints marked *Pause and try* are the key steps.



Ask yourself Put the batsman at the origin and the fielder at distance D . If the ball is at (x, y) , what is $\tan \theta$?

STAGE 1 The perfectly placed fielder



Ask yourself Let the ball have horizontal speed U and initial vertical speed W , and let it land (at eye level) at time T . Write x , y and D in terms of U , W , T , g and t . Can you factorise y ?

STAGE 2 The running fielder



Ask yourself Now the fielder starts at distance D_0 and runs towards the batsman at speed v , so her position is $D_0 - vt$. She catches the ball at time T . What is D_0 ? Repeat the calculation.



Ask yourself The question asks for the converse: if she runs so that $\frac{d}{dt} \tan \theta$ is constant, will she catch the ball?

Try this next

- 1 Running backwards.** If the ball will land behind the fielder's starting position, show that she should run away from the batsman, and that the same rule applies.
- 2 Not θ itself.** Show that, for a perfectly placed fielder, $\frac{d\theta}{dt}$ is not constant. Why is $\tan \theta$ the right quantity to watch?
- 3 Eye level.** If the ball is struck from a height h below the fielder's eye level, is $\tan \theta$ still linear in t for a well-placed fielder? (Assume she catches it at eye level.)
- 4 Air resistance.** With linear air resistance, the horizontal velocity decays exponentially. Is $\tan \theta$ still linear in t for a well-placed fielder?

Further reading

- Seville Chapman, "Catching a baseball", *American Journal of Physics* 36 (1968).
- Michael McBeath, Dennis Shaffer & Mary Kaiser, "How baseball outfielders determine where to run to catch fly balls", *Science* 268 (1995).

- **Dennis Shaffer et al., “How dogs navigate to catch Frisbees”, *Psychological Science* 15 (2004).**

The full guided solution, and what the question leads to at university, is in Section 11.11:
https://keithmcnulty.github.io/step_book_mcnulty/ch11/fielders.html