With what minimum speed does a baseball have to come off the bat to clear the Green Monster at Fenway Park? The wall is 115.5 m from home plate and 11.3 m high. Assume the batter makes contact 1.0 m off the ground at an angle of 65°.

- This problem is asking us to solve for the speed of the ball, *v*. What makes it challenging is that no velocities in any direction or time is given.
- We will start with our first principle equations and develop a formula that only has the variable *v*.
- First, list known information and equations in each direction.

x - direction	***y - direction***
$d_{ox} = 0\ m$ $d_{fx} = 115.5\ m$ **eq1**: $v_x = v\ cos\ 65$ (horizontal component) **eq2**: $v_x = \frac{d_{fx}-d_{ox}}{t} = \frac{115.5-0}{t}$ (velocity formula) Eliminating v_x gives us: **eq3**: $v\ cos\ 65 = \frac{115.5}{t}$	$d_{oy} = 1.0\ m$ $d_{fy} = 11.3\ m$ **eq4**: $v_{oy} = v \sin 65$ (vertical component) **eq5**: $11.3 = 1.0 + v_{oy}t + \frac{1}{2}(-9.81)t^2$ (vertical position) We use the d_{fy} equation because it contains variables given in the question.

- Now to do some equation manipulation. Remember the purpose is to create one equation with the only know variable the velocity, *v*.
  - There is nothing more we can do with the equations in the *x-direction*. We eliminated v_x and we are left with an equation with *v* and *t*. Let us move on to the *y-direction*.
  - We do not have, nor want to calculate, v_{oy} so we will eliminate it by substituting **eq4** into **eq5**:

eq6: $$11.3 = 1.0 + (v \sin 65)t - 4.9t^2$$

  - This helps solve the problem because now we have two equations and two unknowns (**eq3** & **eq6**):

eq3: $$v\ cos\ 65 = \frac{115.5}{t}$$

eq6: $$11.3 = 1.0 + (v \sin 65)t - 4.9t^2$$

  - One more substitution and we will have our final equation. Since we are trying to find velocity, *v*, we will eliminate the time variable, *t*, in **eq6**.
  - First we need to rearrange **eq3** to solve for time, *t*:

eq3: $$t = \frac{115.5}{v \cos 65}$$

  - Now substitute **eq3** into **eq6** to eliminate time:

$$11.3 = 1.0 + (v \sin 65)\left(\frac{115.5}{v \cos 65}\right) - 4.9\left(\frac{115.5}{v \cos 65}\right)^2$$

  - The *v*-variable in the middle term divides out, a trig identity simplifies *sin* and *cos* and using exponent laws on the quadratic term gives:

$$11.3 = 1.0 + 115.5 \tan 65 - 4.9\left(\frac{115.5^2}{v^2(\cos 65)^2}\right)$$

  - This now becomes easier to solve, just be careful with your math and you should get ***v = 39.3 m/s***