# More Challenging Kinematics Problems

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## Type 1: Lack of information or interpeting solutions.

— Lack of information
- use context, and ideas learned like projectile symmetry or constants like gravity on Earth ($-9.8 m/s^2$)

Ex. A dog jumps straight up with a velocity of 2.7m/s. How long is it in the air?

Known From:

$v_i = 2.7 m/s$
$v_f = -2.7 m/s$ ← symmetry
$a = -9.8 m/s^2$ ← Earth's gravity
$d = 0 m$ ← starts & stops in the same place.
$t = ?$

Interpretation

Ex. A ball is hit in left field and has a vertical velocity of 5.2m/s up. Jim takes 7s to get to the ball. Does he catch it? The ball is above the ground. $d > 0$

$v_i = 5.2 m/s$
~~$v_f =$~~
$a = -9.8 m/s^2$
$d =$
$t = 7s$

What do we need to find out?
How fast or where Jim gets the ball?

$$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$\vec{d} = 5.2(7) + \frac{1}{2}(-4.9)(7)^2$$

$$\vec{d} = 36.4 + -240.1$$

$$\vec{d} = -203.7 m$$

What does this mean?
Jim catches the ball 203.7m underground.

— Does this make sense?
No

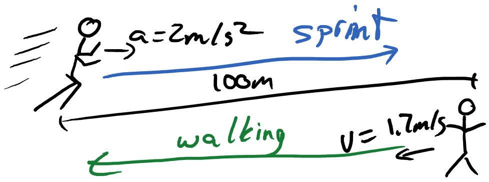
-Does this make sense?

No

Jim does not catch the ball.

## Type 2: Two Motion Problems

Easier Ex. Graham sprints 100m starting at rest and accelerates at $2m/s^2$. After the sprint Graham walks back to his starting point going a constant 1.7m/s. How long does it take Graham to do one walk/sprint cycle?




① Sketch the situation

② Split the problem into two motions.

③ Identify values that are the same, or relationships between the two values.

④ Problem Solve

**Sprint**

$v_i = 0m/s$

$v_f =$

$a = 2m/s^2$

$d_s = 100$

$t_s$

**Walk**

~~$v_i$~~ = constant velocity

~~$v_f$~~ = $v_w = -1.7m/s$

~~$a$~~

$d_w = -100m$

$t_w =$

$v = \frac{d}{t}$

$t_{Total} = t_s + t_w$

$d_s = v_i t_s + \frac{1}{2} a t_s^2$

$100 = \cancel{0 t_s} + \frac{1}{2}(2)t_s^2$

$100 = t_s^2$

$t_s = 10s$

$t_w = \frac{d_w}{v_w}$

$t_w = \frac{-100}{-1.7}$

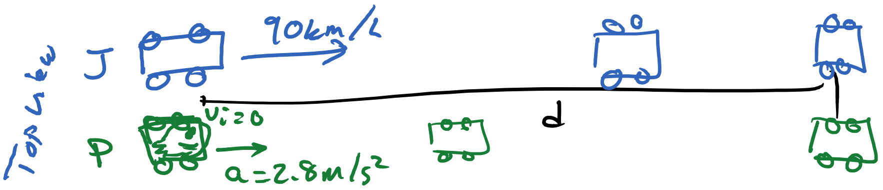
$t_w = 58.8s$

$t_{Total} = 10s + 58.8s$

$\boxed{t_{Total} = 68.8s}$

Harder Ex. Jasmine is speeding, going 90km/h in a 50km/h zone. A police ghost car at rest begins to accelerate the moment Jasmine passes it.

If it accelerates at 2.8 m/s, how long does it take to catch up with Jasmine?




| Jasmine (const vel.) | Police |
|---|---|
| $v_J = 90\, km/h = 25\, m/s$ | $v_i = 0\, m/s$ |
| | $a_p = 2.8\, m/s^2$ |
| $d =$ ← same → | $d =$ |
| $t =$ ← same → | $t =$ |

④ Use Substitution to eliminate a variable

$v = \frac{d}{t}$

$d = (v_J \cdot t)$ substitute → $d = v_i t + \frac{1}{2} a t^2$

$v_J t = v_i t + \frac{1}{2} a_p t^2$

$25t = 0t + \frac{1}{2}(2.8)t^2$

$\frac{25\cancel{t}}{\cancel{t}} = \frac{1.4t^{\cancel{2}}}{\cancel{t}}$

$\frac{25}{1.4} = \frac{1.4t}{1.4}$

$\boxed{t = 17.9\, s}$

The ghost car takes 17.9s to catch up to Jasmine.

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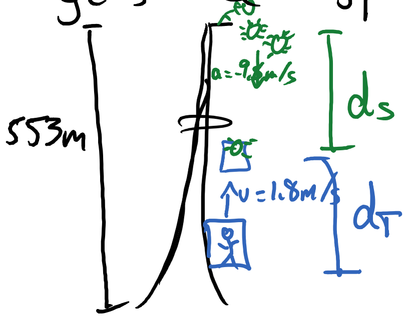
Actually Hard Ex. Thomas goes to the CN Tower (553m). He board the elevator that will travel up the tower at a rate of 1.8 m/s. Ally is on the top of the tower and drop spider at the same moment Thomas' elevator starts moving.

How high off the ground is Thomas when he gets a spooky surprise?




**Spider**

$v_i = 0$ m/s

$a_s = -9.8$ m/s²

$d_s = d_T - 553$

$t =$

**Thomas**

$v_T = 1.8$ m/s

$d_T = 553 + d_s$

$t =$

same

$553\text{m} = d_T - d_s$ Use Substitution

$t = \frac{d_T}{v_T}$

$d_s = v_i t + \frac{1}{2} a_s t^2$

$d_s = v_i\left(\frac{d_T}{v_T}\right) + \frac{1}{2} a_s \left(\frac{d_T}{v_T}\right)^2$

$d_s = 0\left(\frac{d_T}{1.8}\right) + \frac{1}{2}(-9.8)\left(\frac{d_T}{1.8}\right)^2$

$d_s = -\frac{4.9\, d_T^2}{3.24} \Rightarrow d_s = -1.512\, d_T^2$

$d_T - 553 = -1.512\, d_T^2$

$\underbrace{1.512}_{a} d_T^2 + \underbrace{d_T}_{b=1} \underbrace{-553}_{c} = 0$

$d_T = \frac{-1 \pm \sqrt{1^2 - 4(1.512)(-553)}}{2(1.512)} = \frac{-1 \pm \sqrt{1 + 3344.544}}{3.024}$

$d_T = \frac{-1 \pm 57.84}{3.024}$ $+ \rightarrow$ 18.8m, $- \rightarrow$ ~~-19.5m~~

Thomas is 18.8m above the ground when spiders land on him.