

Week 3 Challenge Homework

1-D Kinematics

Submit a digital copy (PDF, jpg, etc.) to gradescope.com. Please use the Gradescope interface to associate each page of your submission with the corresponding question number! It makes grading much easier.

Every page should be labeled on the top left with the question number and there should be only be one solution per page. If a solution takes more than one page, be sure to label that it is a continuation of the previous page's solution. If data is needed to complete a problem, be sure to cite the source you've acquired your data from. See the course website for further details.

You will be asked to apply sense-making in some problems. Use the list below as a reference to the different sense-making techniques. More information about sense-making can be found on the BoxSand menu under Math Tools => [Sense-making](#).

- *Sign*: Check the **sign** of each quantity makes sense.
- *Dimensionality*: Check the **dimensionality** and units of each quantity makes sense.
- *Order of Magnitude*: Check the **order of magnitude** of the final answer and other important quantities is within a factor of 10 of what you think it should be.
- *Graphical Analysis*: Use a **graph** to see if the behavior of a solution makes sense.
- *Proportionality*: Using a symbolic solution, check the behavior of the answer when you change a given quantity on which it is dependent. Does the answer vary **proportionally** to what you expect?
- *Special Cases*: Check the behavior of a derived equation in limiting (**special**) cases makes sense, e.g. as x goes to 90 degrees in $\sin(x)$.
- *Self-consistency*: Check derived equations, functions, or values, are **self-consistent**, e.g. check that the slope of a derived position plot matches the values of the given velocity plot
- *Known Values*: Compare given or derived quantities with common well **known values**.
- *Related Quantities*: Compare the relative magnitude of two **related quantities**.

Question 1:

Two bacteria are next to each other moving in the same direction. One moves with an initial velocity of $20 \mu\text{m/s}$, accelerating at a rate of $5 \mu\text{m/s}^2$. The other starts with a velocity of $60 \mu\text{m/s}$ and is decelerating at a rate of $2 \mu\text{m/s}^2$. $1 \mu\text{m} = 10^{-6} \text{ m}$.

- (a) Find the time and position at which the bacteria meet again for an epic battle.
- (b) Use the *Related Quantities* sense-making technique to compare the position found in part (a) for both bacteria. How do you expect these positions to compare?
- (c) Sketch a plot of the position as a function of time for the two bacteria. Any important feature of the motion should be scaled to the time at which it happened.

Question 2:

A goalie kicks a soccer ball straight vertically into the air. It takes 5.00 s for the ball to reach its maximum height *and* come back down to the level of the crossbar. Assume the crossbar of a soccer goal is 2.44 m above the ground.

- (a) How fast was the ball originally moving when it was kicked?
- (b) How much longer would it take the ball to reach the ground?
- (c) Use the *Order of Magnitude* sense-making technique to verify your answer to part (a) and (b).