

DISPLACEMENT AT MOTION WITH ACCELERATION

OCTOBER 31, 2021

THEORY RECAP

Today we did an experiment together. The goal was to determine free fall acceleration by measuring the time t it takes a ball to fall from some height h . As we have discussed last time, if the ball is initially at rest, then h in terms of g and t is

$$h = \frac{gt^2}{2}$$

For our experiment we need to reverse this formula and express g in terms of h and t . Then by measuring h and t we could calculate free fall acceleration:

$$g = \frac{2h}{t^2}$$

Another thing which we discussed was the formula for displacement when we have acceleration and initial velocity is non-zero. The main idea is the same: for motion with constant acceleration average velocity is exactly in between initial velocity and final velocity. If initial velocity is \vec{v}_0 and an object moves with acceleration \vec{a} , after time t (final) velocity will be $\vec{v}_0 + \vec{a}t$. Average velocity is in between the initial and final velocities:

$$\vec{v}_{avg} = \frac{\vec{v}_0 + (\vec{v}_0 + \vec{a}t)}{2} = \vec{v}_0 + \frac{\vec{a}t}{2}$$

Then displacement is

$$\vec{d} = \vec{v}_{avg}t = \vec{v}_0t + \frac{\vec{a}t}{2}t = \vec{v}_0t + \frac{\vec{a}t^2}{2}$$

As always, pay attention to signs when applying this formula. Assign some direction as positive, then if displacement, velocity or acceleration look in the opposite direction, you should take them with a minus sign.

HOMEWORK

- Several weeks ago we calculated acceleration of Tesla model S Performance based on the fact that it reaches speed $v = 60$ mph in just $t = 2.4$ s. You could use your corresponding homework as a reference if you do not want to calculate everything from scratch.
 - Now find how far does the car travel during this acceleration. *If you want an extra challenge*, try to express the answer via the letters (v and t) and only then plug in the numbers.
 - We have also found previously how long it would take to brake from 60 mph with acceleration 4 m/s^2 . Now find the braking distance (how far does the car travel during braking before it stops).
- You have a bet with your friend that you could throw a ball higher than the roof of your school. Your school is 6 m high. You throw the ball vertically up with initial speed 15 m/s.

- (a) In what time will it reach the highest point? (hint: at highest point the ball has to stop - if it has not stopped yet it would go even higher)
- (b) What height will the ball reach? Did you win the bet?
- (c) In what time after you threw it will it return to the ground?

The following problem is a bonus problem.

- *3.** You stay next to the front door of the first carriage of a train on a train station. The train starts to move with a constant acceleration. You notice that exactly in 3 seconds after the train started moving the front door of the second carriage passes you. How many carriages will move past you in the following 3 seconds? And then in the next 3 seconds? Assume that it's a very long train and all the carriages have the same length.