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PHY 1110 - Summer 2020 - Study Guide #2 - One-Dimensional Kinematics

THE "MAGIC FORMULAS" OF KINEMATICS

Constant velocity:	$x - x_o = v\,t$	
Constant acceleration	$x - x_o = \frac{1}{2}(v + v_o)\,t = v_{ave}\,t$	does not contain "a"
	$v - v_o = a\,t$	does not contain "x"
	$v^2 - v_o^2 = 2\,a\,(x - x_o)$	does not contain "t"
	$x - x_o = v_o\,t + \frac{1}{2}\,a\,t^2$	does not contain "v"

These formulas should be memorized because they come up many times throughout the year. After using them a few times you should remember them without too much effort. If you are unsure if you remember the formula correctly, check the consistency of the units in the formula.

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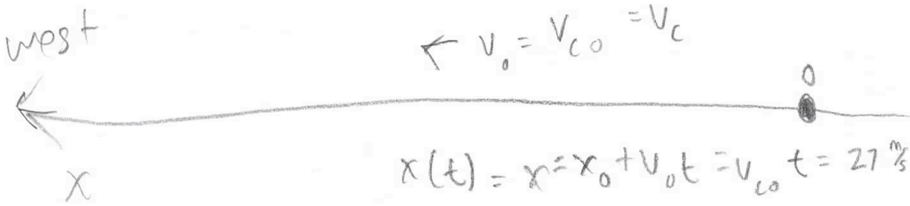
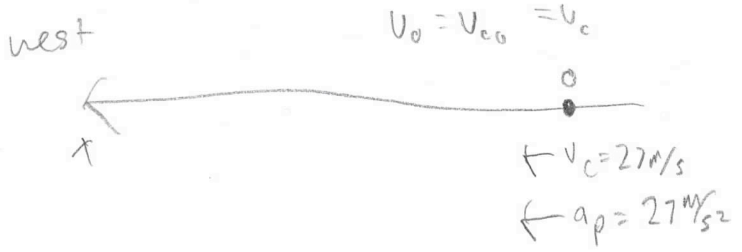
1. A Corvette traveled down a long straight road in a westerly direction with a <u>constant velocity</u> of 27 m/s. As it passed a large apple tree along the side of the road, an observant traffic policeman started a timer. Sketch the situation, set up a coordinate system, and list the information known about the Corvette in <u>proper mathematical notation</u>. Let $t_o = 0$ s as the Corvette passed the tree.

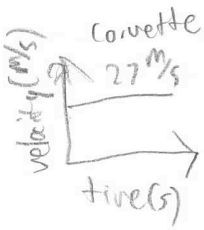


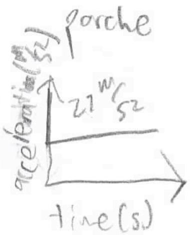
$x(t) = x = x_0 + v_0 t = v_{c0}\,t = 27\,\frac{m}{s}\,t$

$x(t_0) = x(t_0 = 0) = x(0) = x_0 = 0$

2. As the Corvette passed the apple tree, a Porsche parked next to the apple tree started moving in the same direction with a <u>constant acceleration</u> of 27 m/s². Sketch the situation, set up a coordinate system that matches the one used for the Corvette, and list the information known about the Porsche in proper mathematical notation. Let $t_o = 0$ s as the Porsche passed the tree.







3. The time required for the Corvette to reach a point 100 m beyond the apple tree was 100/27 s and at that time the velocity of the Corvette was 27 m/s.

$d = d_0 + \frac{1}{2}(V_0 + V)t$

it has aconstant velocity

$100 = 27t$

$t = {}^{100}/_{27}\,s$

4. The velocity of the Porsche 1 s after starting was 27 m/s, and the distance it traveled was 13.5 m (note: answer not 27 m). Its velocity after 5 s was 135 m/s, and the distance it traveled was 337.5. (27 m/s, 13.5 m, 135 m/s, 337.5 m)

$V = V_0 + at$

$V = 0 + 27(1)$

$= 27\ \frac{m}{s}$

$d = d_0 + V_0 t + \frac{1}{2}at^2$

$= 0 + 0(1) + \frac{1}{2}(27)(1)^2$

$= 13.5\,m$

$V = V_0 + at$

$= 0 + 27(5)$

$= 135\ \frac{m}{s}$

$d = d_0 + V_0 t + \frac{1}{2}at^2$

$= 0 + 0(5) + \frac{1}{2}(27)(5)^2$

$= 337.5\,m$

5. At what time t does the Porsche reach a point 100 m from the tree? Since t^2 appears in the formula two answers result: t = 2.72 s and t = -2.72 s. Which is the correct answer here? Why? (+2.72 s, -2.72 s)

$d = d_0 + V_0 t + \frac{1}{2}at^2$

$100 = 0 + 0(t) + \frac{1}{2}(27)t^2$

$7.4074 = t^2$

$t = \pm 2.72$

positive because negative time does not make sense

6. At what time t does the Porsche catches up with the Corvette? At this time $x - x_0$ is the same for both cars. Write formulas for $x - x_0$ for each car, set the formulas equal to one another, and solve for t. This will require doing a little algebra. The quadratic formula must be used to solve for t and two answers result: t = 0 and t = 2. (Circle the correct time and state the physical significance of the other time.) (0 s, +2 s)

$x - x_0 = Vt$

$x - x_0 = V_0 t + \frac{1}{2}at^2$

$Vt = V_0 t + \frac{1}{2}at^2$

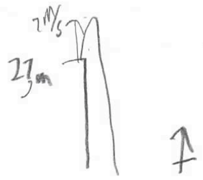
$27t = 0t + \frac{1}{2}(27)t^2$

$13.5t^2 - 27t = 0$

$\frac{27 \pm \sqrt{27^2 - 4(13.5)(0)}}{2(13.5)} = \frac{27 \pm 27}{27} = \frac{0}{27}, \frac{54}{27} = 0, 2$

0s is when the Corvette passed the tree

7. Orville stands at the edge of the roof of Fawcett Hall and throws a Pepsi bottle straight up with an initial velocity of 7 m/s. The bottle rises and then falls, eventually striking the ground 23 m below Orville's hand. Sketch this situation, set up a vertical coordinate system with its origin at the ground and with positive x pointing up. List all the information known about the bottle in proper mathematical form including proper signs. USE THIS COORDINATE SYSTEM IN SOLVING THE FOLLOWING PROBLEMS.



8. When the bottle reaches its highest elevation, its velocity is ___0___ m/s and its acceleration is ___-9.8___ m/s².

9. Find the maximum elevation reached by the bottle by a two step method. Use your knowledge of the velocity of the bottle at its maximum height to calculate the time t = ___0.714___ s when the bottle reaches this height. Then calculate the height x = ___25.5___ m of the bottle at this time. This maximum height is ___2.5___ m above the height of Orville's hand when he released the bottle. (+0.714 s, +25.5 m, 2.5 m)

$V = V_0 + at$

$0 = 7 + (-9.8)t$

$t = 0.714$

$d = d_0 + V_0 t + \frac{1}{2}at^2$

$= 23 + 7(0.714) + \frac{1}{2}(-9.8)(0.714)^2$

$= 25.5$

$25.5 - 23 = 2.5$

10. The maximum elevation can also be calculated in one step. Simply use your knowledge of the velocity of the bottle at its maximum height to directly calculate the elevation x = ___25.5___ m at which the bottle has this velocity. The elevation found by the two step method (a) is in good agreement with, (b) is close to, or (c) is in disagreement with the elevation calculated by the two-step method.

$v^2 = v_0^2 + 2a(d - d_0)$

$0^2 = 7^2 + 2(-9.8)(d - 23)$

$0 = 49 + 450.8 - 19.6d$

$-499.8 = -19.6d$

$d = 25.5$

11. The velocity of the bottle when it strikes the ground can also be found by a one-step or a two-step method. The two step method consists of first calculating the time when the bottle strikes the ground and using this result to calculate the velocity.

a) The time calculation gives two results, t = 3 s and t = -1.57 s. The correct result is 3. What is the physical significance of the second result? (+3.00 s, -1.57 s)

$d = d_0 + V_0 t + \frac{1}{2} a t^2$

$0 = 23 + 7(t) + \frac{1}{2}(-9.8)t^2$

$0 = 23 + 7t - 4.9t^2$

$4.9t^2 - 7t - 23 = 0$

$\frac{7 \pm \sqrt{7^2 - 4(4.9)(-23)}}{2(4.9)} = \frac{7 \pm \sqrt{499.8}}{9.8} = 2.99, -1.57$

-1.57 = the time it would take to throw the bottle up to 23 m following the arc

b) The velocity calculated using this time is -22.4 m/s. (-22.4 m/s)

$V = V_0 + at$

$7 = V_0 + (-9.8)(3.57)$

$V_0 = -22.4$

12. The velocity of the bottle as it strikes the ground can also be calculated in a single step. This calculation gives two values because of the v^2 which is present in the formula. The results are v = 22.4 m/s and v = -22.4 m/s. What is the physical significance of the second value?

$V^2 = V_0^2 + 2a(d - d_0)$

$v^2 = 7^2 + 2(-9.8)(0 - 23)$

$V = \sqrt{499.8}$

$V = \pm 22.36$

the velocity it would need to be thrown up at to have the same arc.

13. The height at which the bottle reaches a velocity of +4 m/s is x = 24.7 m. This occurs (a) on the way up, (b) on the way down, or (c) both on the way up and the way down. (+24.7 m)

$V_f^2 = V_0^2 + 2a(d - d_0)$

$4^2 = 7^2 + 2(-9.8)(d - 23)$

$16 = 49 + (-19.6)(d - 23)$

$-33 = 450.8 - 19.6d$

$19.6d = 483.8$

$d = 24.68$