§ 1 Physics Club Kinematics Problem Set

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Instructions: On the $F = ma$ exam, only hand-held calculators are allowed or scientific calculators if only "basic functions" are used. However, some University Physics problems require the use of advanced calculator functions.

Review

1. Derive the following kinematic equations. *Hint*: For the first two, draw velocity vs. time graphs and analyze each. For the third, use the second and make a substitution for time. (No Calculus)

   a) $v_f = v_0 + at$

   b) $\Delta x = v_o t + \frac{1}{2}at^2$

   c) $v^2 = v_0^2 + 2a\Delta x$

Easy

1. A ball rolls from the back of a large truck traveling 10.0 m/s to the right. The ball is traveling horizontally at 8.0 m/s to the left relative to an observer in the truck. The ball lands on the roadway 1.25 m below its starting level. How far behind the truck does it land? (2016 $F = ma$)

2. A 600 meter wide river flows directly south at 4.0 m/s. A small motor boat travels at 5.0 m/s in still water and points in such a direction so that it will travel directly east relative to the land. How long does it take to cross the river? (2015 $F = ma$)

3. A car travels directly north on a straight highway at a constant speed of 80 km/hr for a distance of 25 km. The car then continues directly north at a constant speed of 50 km/hr for a distance of 75 more kilometers. What is the average speed? (2015 $F = ma$)

4. An observer stands on the side of the front of a stationary train. When the train starts moving with constant acceleration, it takes 5 seconds for the first car to pass the observer. How long will it take for the 10th car to pass? (2013 $F = ma$)

5. Consider a dripping faucet, where the faucet is 10 cm above the sink. The time between drops is such that when one drop hits the sink, one is in the air and another is about to drop. At what height above the sink will the drop in the air be right as a drop hits the sink? Express your answer as a range between two consecutive even integers (ex. 0-2 meters) (2012 $F = ma$)

6. A cannonball is launched with initial velocity of magnitude v_0 over a horizontal surface. At what minimum angle θ_{min} above the horizontal should the cannonball be launched so that it rises to a height H which is larger than the horizontal distance R that it will travel when it returns to the ground? If this is not possible, explain why. (2012 $F = ma$)

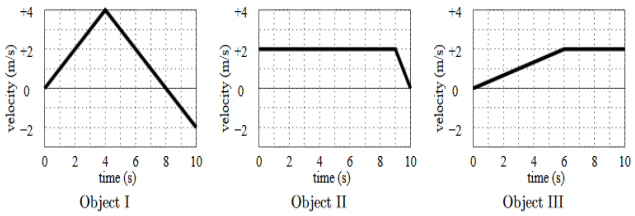
7. Two cannons are arranged vertically, with the lower cannon pointing upward (towards the upper cannon) and the upper cannon pointing downward (towards the lower cannon), 200m above the lower cannon. Simultaneously, they both fire. The muzzle velocity of the lower cannon is 25m/s and the muzzle velocity of the upper cannon is 55m/s. (2012 $F = ma$)

   a) How long after the cannons fire do the projectiles collide?

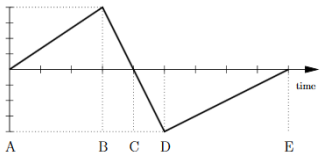
   b) How far beneath the top cannon do the projectiles collide?

8. A cyclist travels at a constant speed of 22.0 km/hr except for a 20 minute stop. The cyclist's average speed was 17.5 km/hr. How far did the cyclist travel? (2011 $F = ma$)

9. Rank the magnitudes of the average acceleration, maximum velocity, and distance traveled during the ten second interval. Example: III>I>II (2011 $F = ma$)



10. The following figure represents the motion of a squirrel as it runs in a straight-line along a telephone wire. The letters denote specific times. (2010 $F = ma$)



a) If the graph is a graph of POSITION vs. TIME, then the squirrel has the greatest speed at what time(s) or during what time interval(s)?

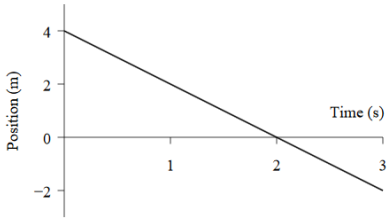
b) If, instead, the graph is a graph of VELOCITY vs. TIME, then the squirrel has the greatest speed at what time(s) or during what time interval(s)?

c) If, instead, the graph is a graph of ACCELERATION vs. TIME and the squirrel starts from rest, then the squirrel has the greatest speed at what time(s) or during what time interval?

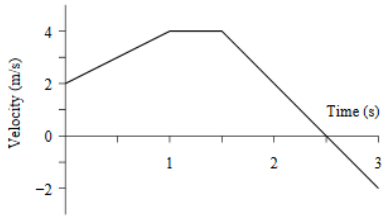
11. A bird is flying in a straight line initially at 10 m/s. It uniformly increases its speed to 15 m/s while covering a distance of 25 m. What is the magnitude of the acceleration of the bird? (2010 $F = ma$)

12. A person standing on the edge of a fire escape simultaneously launches two apples, one straight up with a speed of 7 m/s and the other straight down at the same speed. Ho w far apart are the two apples 2 seconds after they were thrown, assuming that neither has hit the ground? (2010 $F = ma$)

13. The position vs. time graph for an object moving in a straight line is shown below. What is the instantaneous velocity at t= 2 s? (2008 $F = ma$)



14. Shown below is the velocity vs. time graph for a toy car moving along a straight line. (2008 $F = ma$)

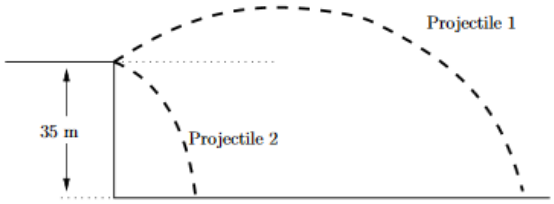


a) What is the maximum displacement from start for the toy car?

b) Draw an acceleration *vs.* time roughly representing the toys path

Medium

1. Two projectiles are launched from a 35 meter ledge as shown in the diagram. One is launched from a 37 degree angle above the horizontal and the other is launched from 37 degrees below the horizontal. Both of the launches are given the same initial speed $v_0 = 50$ m/s.



The difference in times of flight for these two projectiles $t_1 - t_2$, is closest to how many seconds, rounded to the nearest whole number?

2. A projectile is launched across flat ground at an angle to the horizontal and travels in the absence of air resistance. It rises to a maximum height H and lands a horizontal distance R away. What is the ratio H/R? (2011 $F = ma$)

3. During your summer internship for an aerospace company, you are asked to design a small research rocket. The rocket is to be launched from rest from the earth's surface and is to reach a maximum height of 960 m above the earth's surface. The rocket's engines give the rocket an upward acceleration of 16.0 m/s^2 during the time T that they fire. After the engines shut off, the rocket is in free fall. Ignore air resistance. What must be the value of T in order for the rocket to reach the required altitude? (*University Physics*, 14th ed.)

4. A helicopter carrying Dr. Evil takes off with a constant upward acceleration of 5.0 m/s^2. Secret agent Austin Powers jumps on just as the helicopter lifts off the ground. After the two men struggle for 10.0 s, Powers shuts off the engine and steps out of the helicopter. Assume that the helicopter is in free fall after its engine is shut off, and ignore the effects of air resistance. (*University Physics*, 14th ed.)

a) What is the maximum height above ground reached by the helicopter?

b) Powers deploys a jet pack strapped on his back 7.0 s after leaving the helicopter, and then he has a constant downward acceleration with magnitude 2.0 m/s^2. How far is Powers above the ground when the helicopter crashes into the ground?

5. Two students are canoeing on a river. While heading upstream, they accidentally drop an empty bottle overboard. They then continue paddling for 60 minutes, reaching a point 2.0 km farther upstream. At this point they realize that the bottle is missing and, driven by ecological awareness, they turn around and head downstream. They catch up with and retrieve the bottle (which has been moving along with the current) 5.0 km downstream from the turnaround point. (*University Physics*, 14th ed.)

   a) Assuming a constant paddling effort throughout, how fast is the river flowing?

   b) What would the canoe speed in a still lake be for the same paddling effort?

Difficult

1. A projectile is launched with speed v_0 off the edge of a cliff of height h, at an angle θ from the horizontal. Air friction is negligible. To maximize the horizontal range of the projectile, θ should be in what range? (2017 $F = ma$)

2. In the vertical jump, an athlete starts from a crouch and jumps upward as high as possible. Even the best athletes spend little more than 1.00 s in the air (their "hang time"). Treat the athlete as a particle and let y_{max} be his maximum height above the floor. To explain why he seems to hang in the air, calculate the ratio of the time he is above $\frac{y_{max}}{2}$ to the time it takes him to go from the floor to that height. Ignore air resistance. (*University Physics*, 14th ed.)

3. A student is running at her top speed of 5.0 m/s to catch a bus, which is stopped at the bus stop. When the student is still 40.0 m from the bus, it starts to pull away, moving with a constant acceleration of 0.170 m/s^2. (*University Physics*, 14th ed.)

   a) For how much time and what distance does the student have to run at 5.0 m/s before she overtakes the bus?

   b) If the student's top speed is 3.5 m/s, will she catch the bus?

   c) What is the minimum speed the student must have to just catch up with the bus? For what time and what distance does she have to run in that case?

4. A ball is thrown straight up from the edge of the roof of a building. A second ball is dropped from the roof 1.00s later. Ignore air resistance. (*University Physics*, 14th ed.)

   a) If the height of the building is 20.0m, what must the initial speed of the first ball be if both are to hit the ground at the same time? Consider the same situation, but now let the initial speed v_0 of the first ball be given and treat the height h of the building as an unknown:

   b) What must the height of the building be for both balls to reach the ground at the same time if (i) v_0 is 6.0 m/s and (ii) v_0 is 9.5 m/s ?

   c) If v_0 is greater than some value v_{max}, no value of h exists that allows both balls to hit the ground at the same time. Solve for v_{max}.

   d) If v_0 is less than some value v_{min}, no value of h exists that allows both balls to hit the ground at the same time. Solve for v_{min}.

5. (Calculus Required) A projectile thrown from a point P moves in such a way that its distance from P is always increasing. Find the maximum angle above the horizontal with which the projectile could have been thrown. Ignore air resistance. (*University Physics*, 14th ed.)

6. A rocket designed to place small payloads into orbit is carried to an altitude of 12.0 km above sea level by a converted airliner. When the airliner is flying in a straight line at a constant speed of 850 $\frac{km}{h}$, the rocket is dropped. After the drop, the airliner maintains the same altitude and speed and continues to fly in a straight line. The rocket falls for a brief time, after which its rocket motor turns on. Once that motor is on, the combined effects of thrust and gravity give the rocket a constant acceleration of magnitude $3.00g$ directed at an angle of 30.0 degrees above the horizontal. For safety, the rocket should be at least 1.00 km in front of the airliner when it climbs through the airliner's altitude. Your job is to determine the minimum time that the rocket must fall before its engine starts. Ignore air resistance. (*University Physics*, 14th ed.)