One Dimensional Kinematics
Challenge Problems

Problem 1: One-Dimensional Kinematics:

Two stones are released from rest at a certain height, one after the other.

a) Will the difference between their speeds increase, decrease, or stay the same?

b) Will their separation distance increase, decrease, or stay the same?

c) Will the time interval between the instants at which they hit the ground be smaller than, equal to, or larger than the time interval between the instants of their release?

d) Plot the speed vs. time for both balls in the same plot.

e) Plot the position vs. time of the two balls in the same plot.

Problem 2: Bus stop

A bus leaves a stop at MIT and accelerates at a constant rate for 5 seconds. During this time the bus traveled 25 meters. Then the bus traveled at a constant speed for 15 seconds. Then the driver noticed a red light 18 meters ahead and slams on the brakes. Assume the bus decelerates at a constant rate and comes to a stop some time later just at the light.

a) What was the initial acceleration of the bus?

b) What was the velocity at the bus after 5 seconds?

c) What was the braking acceleration of the bus? Is it positive or negative?

d) How long did the bus brake?

e) What was the distance from the bus stop to the light?

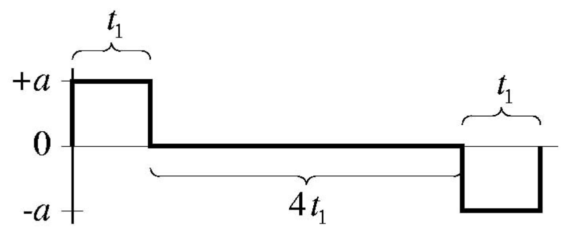
f) Make a graph of the position vs. time for the entire trip.

g) Make a graph of the velocity vs. time for the entire trip.

h) Make a graph of the acceleration vs. time for the entire trip.

Problem 3

A person of given mass m is standing on a scale in an elevator in Building 24. Initially the elevator is at rest. The elevator then begins to ascend to the sixth floor, which is a given distance h above the starting point. The elevator undergoes an unknown constant acceleration a for a given time interval t_1. Then the elevator moves at a constant velocity for a time interval $\Delta t_2 = 4t_1$. Finally the elevator brakes with a deceleration of the same magnitude as the initial acceleration for a time interval $\Delta t_3 = t_1$ until stopping at the sixth floor. Assume the gravitational constant is given as g. Find the magnitude of the acceleration. Briefly explain how you intend to model this problem and write down your strategy for solving it. Estimate the height h and the time interval t_1 and check if your answer makes sense.



Problem 4

A ball is released from rest at a height h above the ground. The ball collides with the ground and bounces up at 75% of the impact speed the ball had with the ground. The collision with the ground is nearly instantaneously. A second ball is released above the first ball from the same height the instant the first ball loses contact with the ground. Calculate the time when the two balls collide and show where the collision occurs on the graph.

Problem 5

A person starts running with a constant velocity trying to catch a streetcar that is initially $2.0 \times 10^1\ \mathrm{m}$ away from the person and has just started to accelerate from rest with a constant acceleration of $0.9\ \mathrm{m \cdot s^{-2}}$. The person runs just fast enough to catch the streetcar and hop on.

a) Describe the strategy you have chosen for solving this problem. You may want to consider the following issues. What does a sketch of the problem look like? What type of coordinate system will you choose? What information can you deduce from a plot of distance *vs*. time for both the person and the streetcar? What conditions must be satisfied when the person just catches up to the streetcar?

b) Now show all your work in answering the following three questions.
   - i) How long did the person run?
   - ii) What is the speed of the person when they just caught up to the streetcar?
   - iii) How far did the person run?

Problem 6

A motorist traveling with constant speed of 15 m/s passes a school-crossing corner, where the speed limit is 10 m/s. Just as the motorist passes, a police officer on a motorcycle stopped at the corner ($x = 0$) starts off in pursuit. The officer accelerates from rest at $a_x = 2.5$ m/s^2 until reaching a speed of 20 m/s. The officer then slows down at a constant rate until coming alongside the car at x = 360 m, traveling with the same speed as the car. a) How long does it take for the officer to catch up with the motorist? b) How long does the officer speed up? c) How far is the officer from the corner and from the car when switching from speeding up to slowing down? d) What is the acceleration of the officer when slowing down? e) Draw an x-t graph and a v_x-t graph for the two vehicles.

Problem 7

The scene opens with a mosquito on the line between two approaching hands that are initially a distance D apart. The mosquito is a distance s from the left hand which moves toward the right hand at a speed v_L. The right hand moves towards the left hand at speed v_R. If the mosquito flows towards the left hand at speed v_M, then reverses direction back toward the right hand at the last instant to avoid being struck by the left hand, how far does the mosquito fly before it is killed?

Be sure to clearly outline your strategy so that someone else can apply it to solve the problem.

Problem 8

During a track event two runners, Bob and Jim, round the last turn and head into the final stretch with Bob $2.0\,\mathrm{m}$ in front of Jim. They are both running with the same speed $8.0\,\mathrm{m}\cdot\mathrm{s}^{-1}$. When the finish line is $4.8\times10^{1}\,\mathrm{m}$ away from Jim, Jim accelerates at $1.0\,\mathrm{m}\cdot\mathrm{s}^{-2}$ until he catches up to Bob. Jim then continues at a constant speed until he reaches the finish line.

a) Describe the strategy you have chosen for solving this problem

b) How long did it take Jim to catch Bob?

c) How far did Jim still have to run when he just caught up to Bob?

d) How long did Jim take to reach the finish line after he just caught up to Bob?

Bob starts to accelerate when Jim just catches up to him, and accelerates all the way to the finish line and crosses the line exactly when Jim does. Assume Bob's acceleration is constant.

e) What is Bob's acceleration?

f) What is Bob's velocity at the finish line? Who is running faster?