

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

Physics 8.01T

Fall Term 2004

Class Problem 1:

Section Leader _____

Names _____

Problem 1 A car is driving at a constant but unknown velocity, v_0 , on a straightaway. A motorcycle is a distance d behind the car. Initially, they are both traveling at the same velocity. The motorcycle starts to pass the car by speeding up at a constant acceleration a_m . When the motorcyclist is side by side with the car, the motorcycle stops accelerating and is traveling at twice the velocity of the car. How long does the motorcycle accelerate? What was the initial velocity of the car and motorcycle? How far did the motorcycle travel while accelerating? Express all your answers in terms of the given quantities in the problem.

I. Understand – get a conceptual grasp of the problem

We assume you've recognized the problem is in the domain of kinematics – the quantitative description of motion. What is the problem asking? What are the given conditions and assumptions? What is to be found and how is this determined or constrained by the given conditions?

In particular: how many objects are there, is the motion in 1, 2, or 3 dimensions, is the motion relative or is there some logical absolute reference frame? Qualitatively describe the motion (in each coordinate and of each body if there are several).

Model: Look for the three most common **model motions** – either the velocity or the acceleration is constant or the motion is uniform circular. Often these apply only to part of the time (or to only one body) – i.e. might the acceleration be constant but different before and after the rocket engine stops or between the two racing cars? Is the motion an example of uniform circular motion.

Advice: Write *your own* representation of the problem's stated data: draw a motion diagram (strobe picture), a graph of position or velocity or acceleration vs. time, or a diagram. Make a table of these quantities vs. time if it's

numerical. What are the initial conditions and how do you represent conditions mathematically (e.g. until car A passes car B). A great many problems will involve special motion, perhaps in one or another coordinate: constant velocity, constant acceleration, uniform circular motion, relative motion – learn to recognize these motions. Get the problem into your brain!

Question: 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 car and the motorcycle? What conditions must be satisfied when the person just catches up to the streetcar?

Answer: Note: Your answer should include a sketch and coordinate system for the system where you clearly indicated your choice of origin, positive directions and reference frame; a single graph showing qualitatively the position of the motorcycle and the driver as a function of time.

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Class Problem 1: Solution

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Modeling the problem:

This is a two body problem with each body undergoing one dimensional motion.

First I sketch the problem and introduce a Cartesian coordinate. My first question is where should I choose my origin. I will choose $t=0$ to depict the moment the motorcycle is at the origin and the car is at a positive distance d . At an arbitrary time, I introduce the position functions $x_1(t)$ for the motorcycle and $x_2(t)$ for the car. I denote the time the car overtakes the motorcycle as t_f .

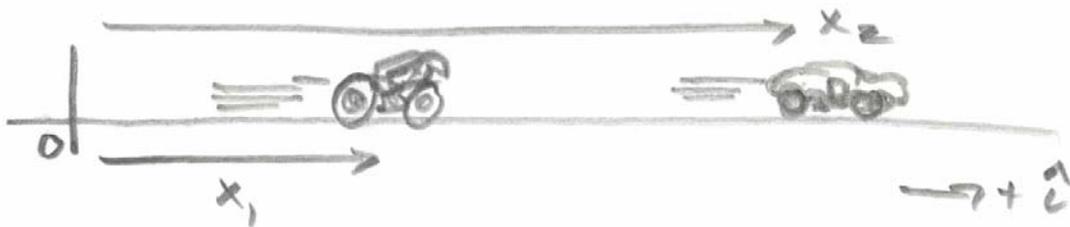


Figure 1: Coordinate System

I am specifically interested in the time period that the motorcycle is accelerating at a constant rate while the car is moving with a uniform velocity. This means that I will need two sets of kinematic equations for position and velocity for the motorcycle and car noting that the acceleration of the car is zero, $a_c = 0$. I can relate these sets of equations by two extra conditions that are stated in the problem. At the moment the motorcycle overtakes the car, the positions are equal and the motorcycle velocity is twice the car. (figure 2).

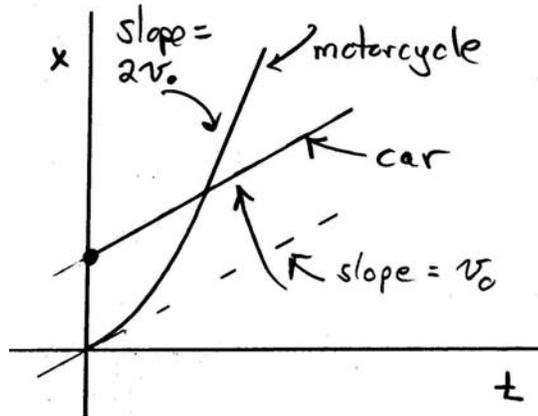


Figure 2: plot of position vs. time for car and motorcycle

The key is to translate all this information into specific equations.

II. ~~Devise a Plan - set up a procedure to obtain the desired solution~~

~~**General** - Have you seen a problem like this - i.e. does the problem fit in a schema you already know? Is a part of the problem a known schema; could you simplify this problem so that it is? Can you find *any* useful results from the given initial conditions and other data even if it is not the solution? Can you imagine a route to the solution if only you know some apparently not given information? Count the unknowns and check that you have that many independent equations.~~

~~**In particular:** choose the best type of coordinate system to simplify the problem, pick the orientation and location of the origin of the coordinate system in accord with the initial conditions. Warning: almost always it is best to pick positive to the right or up and represent downwards acceleration, for example, as $-g$. Given that the problem involves some particular type of motion (constant acceleration, circular motion) think over *all* the equations that involve this concept.~~

~~**Question:** Devise a plan for solving for: how long does the motorcycle accelerate?; what was the initial velocity of the car and motorcycle?; how far did the motorcycle travel while accelerating?~~

Answer:

~~I can write down the kinematic equations for the motorcycle, with the initial position corresponding to my choice of origin, $x_{1,0} = 0$; the initial velocity, the unknown $v_{1,0} = v_0$; and the acceleration of the motorcycle $a_1 = a_m$; then~~