MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

Physics 8.01T **Fall Term 2004**

Class Problem 1:

Section Leader _____________________________________

Names _____________________________________

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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.

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:

III. Carry our your plan – solve the problem!

This generally involves mathematical manipulations. Try to keep them as simple as possible by not substituting in lengthy algebraic expressions until the end is in sight, make your work as neat as you can to ease checking and reduce careless mistakes. Keep a clear idea of where you are going and have been (label the equations and what you have now found), if possible, check each step as you proceed.

Solution:

IV. Look Back – check your solution and method of solution

Can you see that the answer is correct now that you have it – often simply by retrospective inspection? Can you solve it a different way? Is the problem equivalent to one you've solved before if the variables have some specific values?

In particular: Check dimensions if analytic, units if numerical. Check special cases (i.e. if a = 0 does the solution simplify?), check that a general expressions reproduce the given initial conditions. Does it depend sensibly on the various quantities (e.g. is the time greater if the initial velocity is less?)? Is the scaling what you'd expect (time decreases with the square root of the acceleration, distance at some later time proportional to initial velocity)? Is the answer physically reasonable (especially if numbers are given or reasonable ones substituted).

Review the schema of the problem – what is the model, the physical approximations, the concepts needed, and any tricky math manipulation.

Question: Choose what you think are reasonable values for the distance d, and the constant acceleration a_m. What values do you then calculate for how long did the motorcycle accelerate?; what was the initial velocity of the car and motorcycle; and how far did the motorcycle traveled while accelerating? Do your values make sense to you?

Answer: