

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**  
**Department of Physics**

**Physics 8.01T**

**Fall Term 2004**

**Problem Set 3: Newton's Laws of Motion, Motion: Force, Mass, and Acceleration, Vectors  
in Physics Solutions**

**Problem 1: (*Relative Inertial Frames*)**

You and a friend are in an elevator that is rising at constant but unknown velocity  $v_0$ . You are curious to know what speed the elevator is moving. You each happen to be carrying altimeters. You get an idea and drop your keys from a height  $h$  above the floor of the elevator. You hold one altimeter at the point where you dropped the keys and your friend places the other one on the floor. You check your altimeter when you release the keys and find the keys are a height  $d$  above sea level. Your friend checks the other altimeter when the keys hit the floor and finds the keys are the same height  $d$  above sea level. Assume that the gravitational constant is  $g$ . You will analyze this problem from two different reference frames. The first reference frame moves with the elevator. The second reference frame is fixed to the ground.

- a) As seen from a reference frame moving with elevator, how long does it take for the keys to hit the floor?
- b) As seen from a reference frame fixed to the ground, using your result from part a), find an expression for the speed of the elevator in terms of the height  $h$ .
- c) As seen from a reference frame fixed to the ground, what maximum height above sea level did the keys reach?

**Solution**

a) As in your reference frame you are dropping the keys from rest at an height  $h$  above the floor it will take a time  $t = \sqrt{\frac{2h}{g}}$  for them to reach the floor.

b) we know that in the time  $t$  the keys were in free fall the elevator covers a distance  $h$  so the speed of the elevator is:  $v = \sqrt{\frac{hg}{2}}$

c) In this reference frame the keys go up for a time  $\frac{t}{2}$  before falling after that they fall for  $s = \frac{gt^2}{8} = \frac{h}{4}$  the maximum height of the keys is so:  $d + \frac{h}{4}$