MOTION ALONG A STRAIGHT LINE

1. **Railroad:** A man on a railroad platform attempts to measure the length of a train car by walking the length of the train and keeping the length of his stride a constant b meters per step. After he has paced off 12 steps from the front of the train it begins to move, in the direction opposite to his, with an acceleration of a_T $[\frac{m}{steps^2}]$. The end of the train passes him after he has walked another 20 steps. Determine the length of the train car.

2. **Race:** Blythe and Geoff compete in a 1-km race. Blythe's strategy is to run the first 600 m of the race at a constant speed of 4 m/s, and then accelerate with constant acceleration to her maximum speed of 7.5 m/s, which takes her 1 min, and finish the race at that speed. Geoff decides to accelerate with constant acceleration to his maximum speed of 8 m/s at the start of the race and to maintain that speed throughout the rest of the race. It takes Geoff 3 min to reach his maximum speed. Who wins the race?

3. **Lizard:** A lizard is running in a straight line according to the following:

$$x(t) = t^3/3 - t^2 + t$$

He starts at $t = 0$.

(a) Determine $v(t)$.

(b) When is the lizard at rest?

(c) When is the lizard moving in the positive x direction?

(d) When is the lizard moving in the negative x direction?

(e) When does the lizard have zero acceleration?

4. **Catching the Bus:** A student is running at her top speed of v_s to catch a bus, which is stopped at the bus stop. When the student is still a distance d from the bus, it starts to pull away, moving with a constant acceleration of a_0.

(a) For how much time and what distance does the student have to run at v_s before she overtakes the bus?

(b) When she reaches the bus, how fast is the bus traveling?

(c) Sketch an x-t graph for both the student and the bus. Take $x = 0$ at the initial position of the student.

(d) The equations you used in part (a) to find the time have a second solution, corresponding to a later time for which the student and bus are again at the same place if they continue their specified motions. Explain the significance of this second solution. How fast is the bus traveling at this point?

(e) 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?

5. **Balls Off the Roof:** A ball is thrown straight up from the edge of the roof of a building. A second ball is dropped from the roof a time t_1 later. Ignore air resistance.
   (a) If the height of the building is H, what must the initial speed of the first ball be if both are to hit the ground at the same time?
   (b) On a graph, sketch the positions of both balls as a function of time, measured from when the first ball is thrown.
   (c) Consider the same situation, but now let the initial speed $v_0 = v_L$ of the first ball be given and treat the height h of the building as an unknown.

6. **Variable Acceleration**: Consider the motion of a particle that experiences a variable acceleration given by $a_x = a_{0x} + bt$, where a_{0x} and b are constants and $x = x_0$ and $v_x = v_{0x}$ at $t = 0$.
   (a) Find the instantaneous velocity as a function of time.
   (b) Find the position as a function of time.
   (c) Find the average velocity for the time interval with an initial time of zero and arbitrary final time t_F.
   (d) Compare the average of the initial and final velocities to your answer to Part (c). Are these two averages equal? Explain

7. **Rocket Backpack**: A physics professor, equipped with a rocket backpack, steps out of a helicopter at an altitude of H with zero initial velocity. (Neglect air resistance.) For a time t_1, she falls freely. At that time, she fires her rockets and slows her rate of descent at an acceleration of a_r until her rate of descent reaches v_f. At this point, she adjusts her rocket engine controls to maintain that rate of descent until she reaches the ground.
   (a) On a single graph, sketch her acceleration and velocity as functions of time. (Take upward to be positive)
   (b) What is her speed after a time t_1 has elapsed?
   (c) What is the duration of her slowing-down period?
   (d) How far does she travel while slowing dawn?
   (e) How much time is required for the entire trip from the helicopter to the ground?
   (f) What is her average velocity for the entire trip?

8. **Waking the Balrog**: In *The Fellowship of the Ring*, the hobbit Peregrine Took (Pippin for short) drops a rock into a well while the travelers are in the caves of Moria. This wakes a balrog (a bad thing) and causes all kinds of trouble. Pippin heard the rock hit the water 7.5 s after he dropped it.
   (a) Ignoring the time it took the sound to get back up, how deep is the well?
   (b) If the speed of sound is 340 m/s (it was pretty cool in that part of Moria), was it OK to ignore the time it takes sound to get back up? Discuss and support your answer with a calculation.