Name Ashna Khemani Section # 101

One-Dimensional Motion and Gravity:
Kinematics of a Moving Ball
Introduction to Mechanics
University of Pennsylvania

Complete this assignment in paper form, or by typing your answers for each question below. You may talk with other students about this assignment, use a calculator and other tools, ask the teaching team questions, and consult outside sources; however, what you write down must be your own work. On computational problems, please show all steps and box your answer.

Turn this post-lab in the Saturday after your next lab session on Canvas as a single PDF. Please ensure that the PDF is clearly readable. Please do **not** attach it to your lab, as these two assignments are graded separately. Late submissions will be penalized by 10 points for each day that transpires between the deadline and your submission. This assignment is worth a total of 50 points.

1. How can you tell from a position-time graph that a motion is steady (constant velocity)? *(3 points)*

On a position-time graph, constant velocity is shown by a constant linear slope.

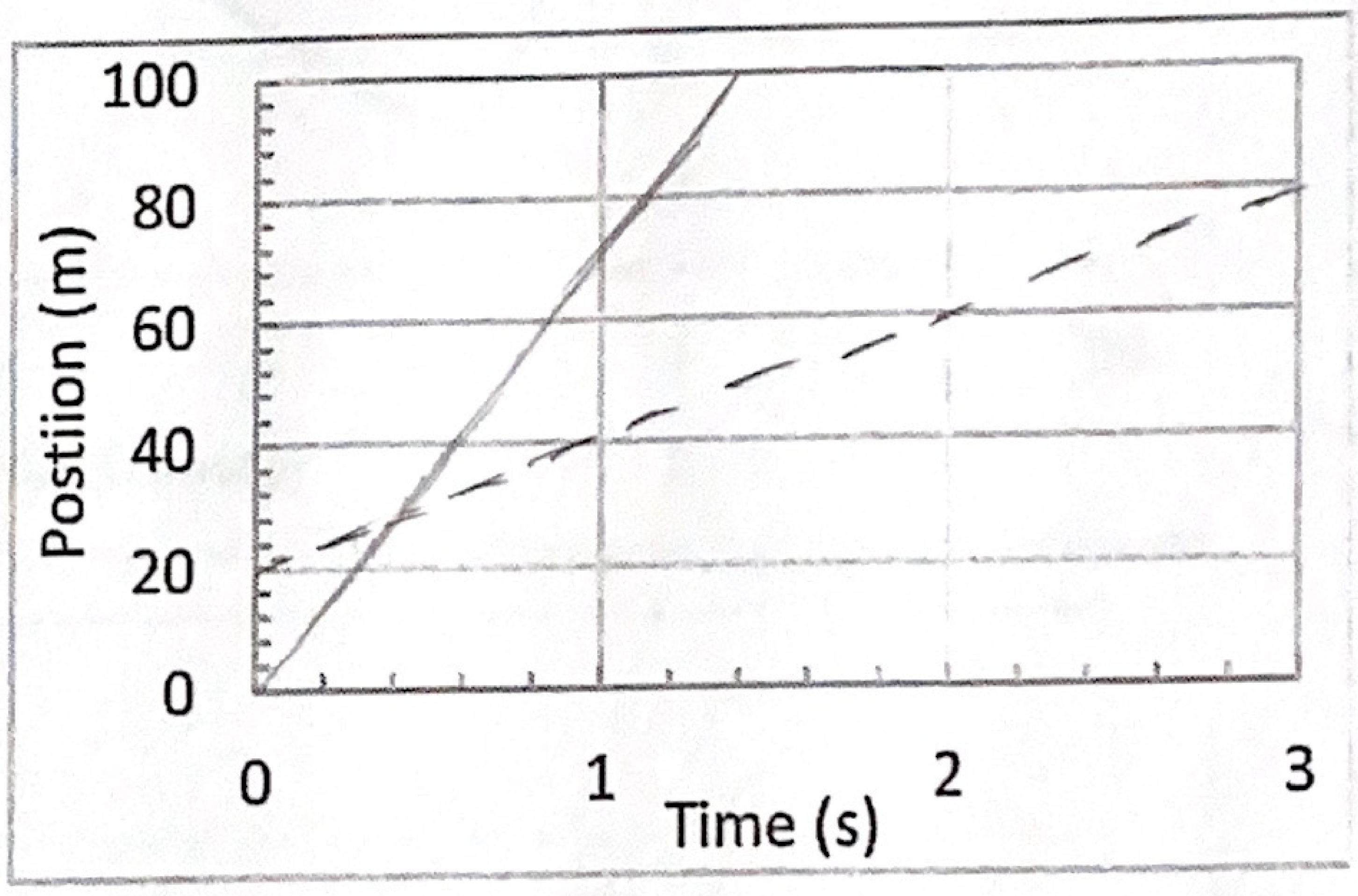
2. How can you tell from an acceleration-time graph that a motion is steady (constant velocity)? *(3 points)*

Costant velocity is shown by $a(t) = 0$ on an acceleration-time graph.

3. When one car passes another on the freeway, which motion variables (position and/or velocity, measured one-dimensionally along the freeway) are instantaneously the same between the two cars? *(3 points)*

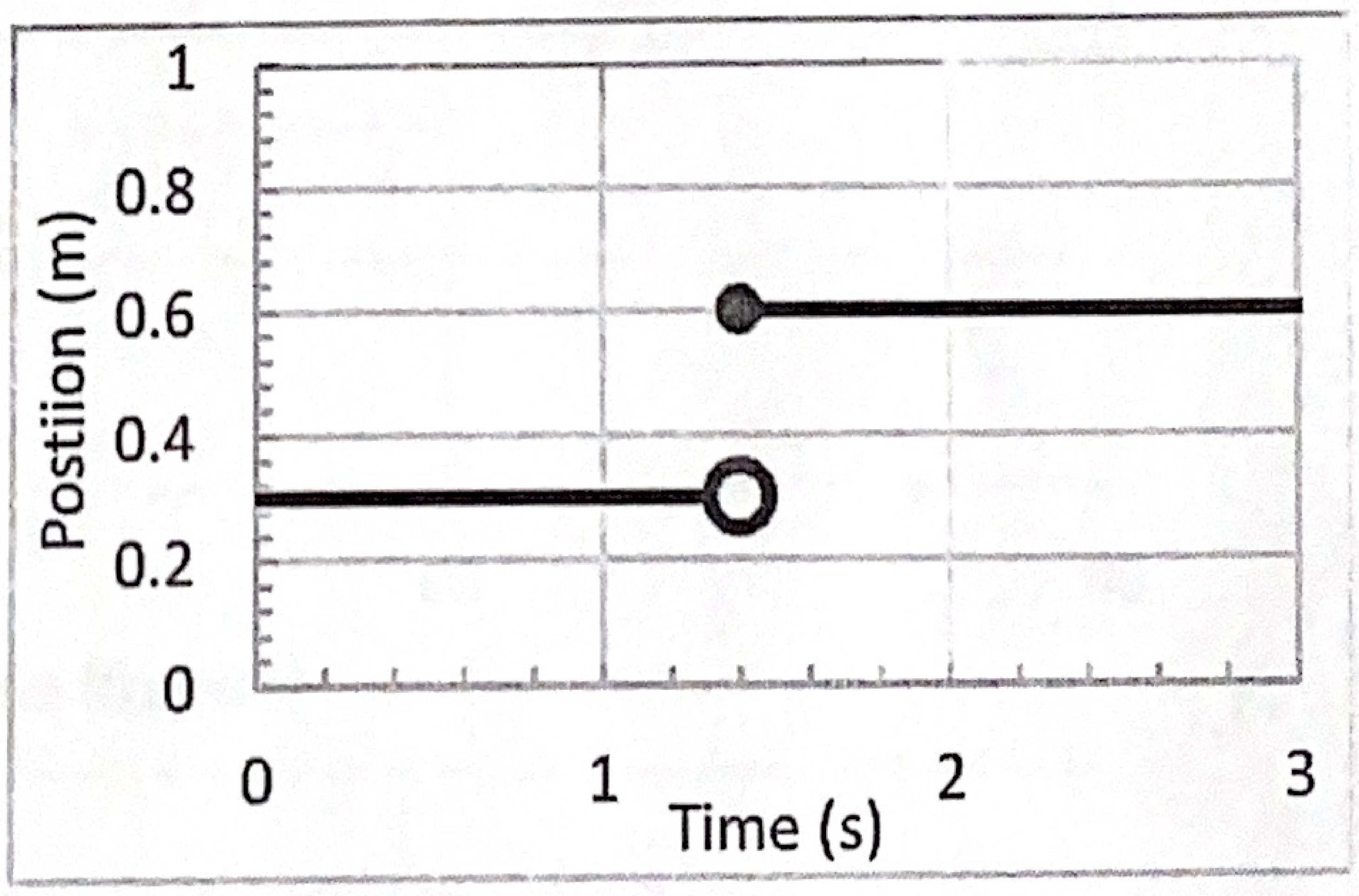
Position is instantaneously the same between the cars.

4. On the axes at right, draw a position-time graph that could correspond to the situation described in the previous question: one car passing another on the freeway. Use a solid line for the passing car and a dashed line for the car being passed. *(3 points)*



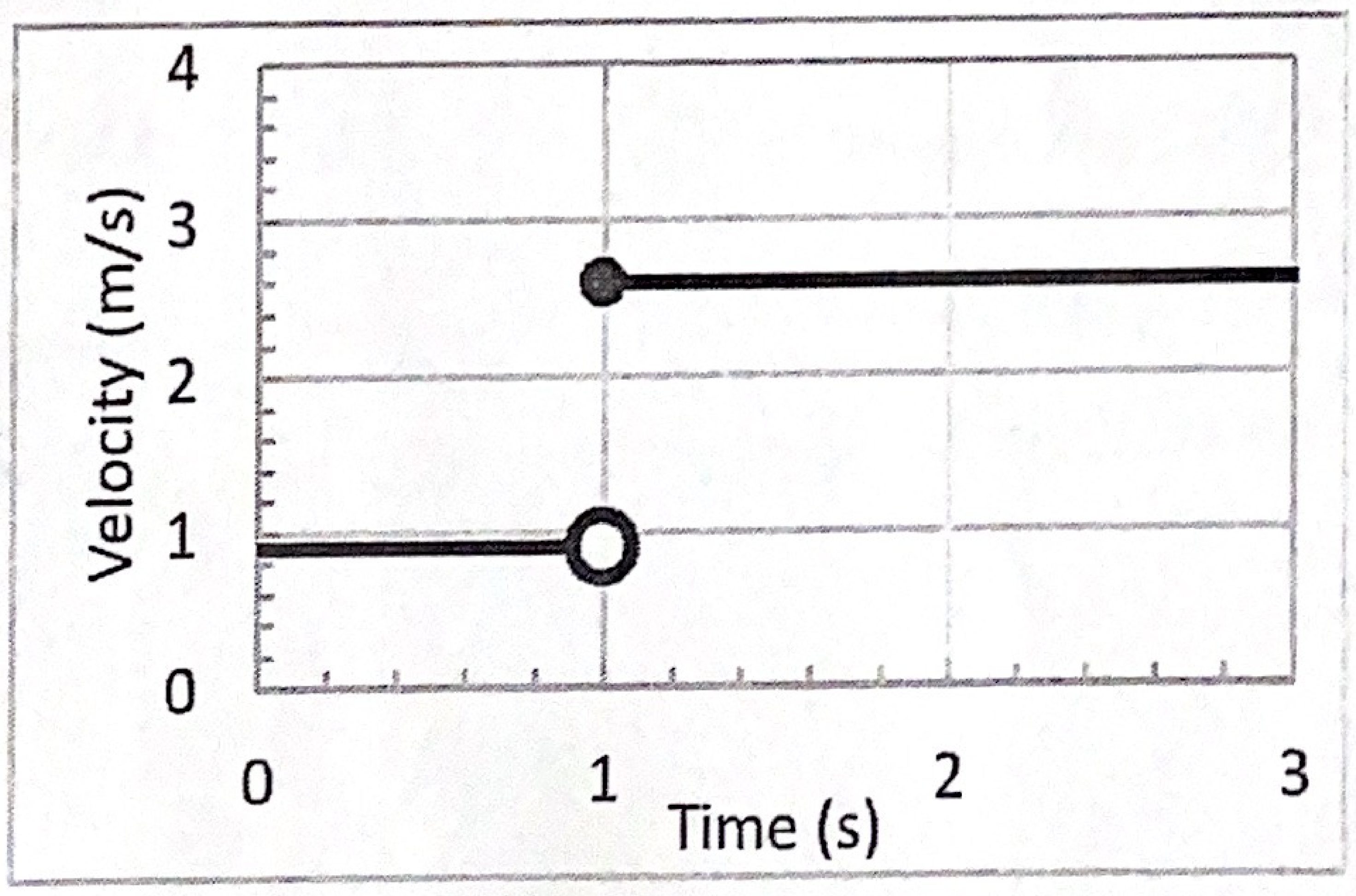
5. Is the motion depicted in the graph at the right physically possible? Explain why or why not. *(3 points)*

No, it's impossible to instantaneously teleport to a new location.

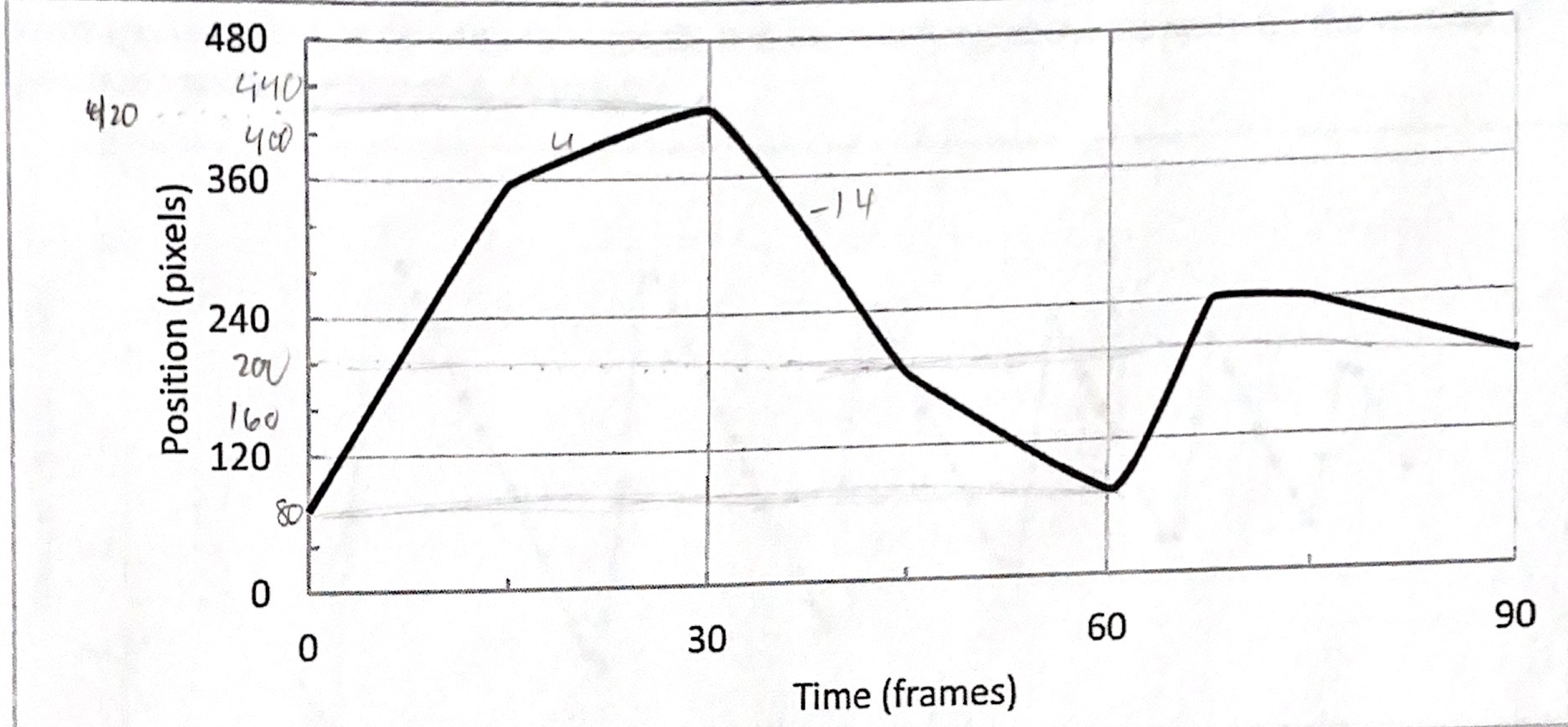


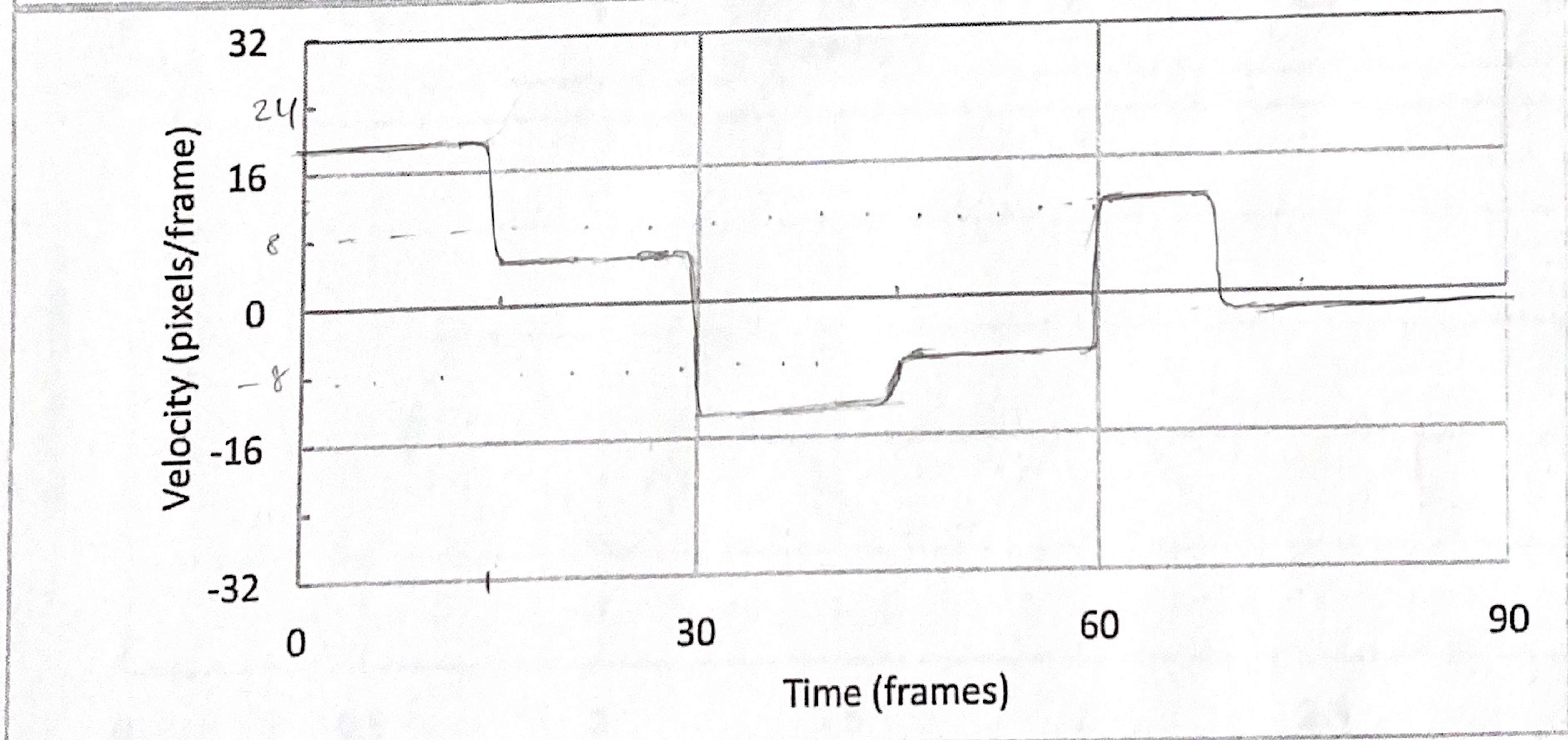
6. Is the motion depicted in the graph at the right physically possible? Explain why or why not. *(3 points)*

No, It suggests infinite acceleration which isn't physically possible in the real world.



7. The graph below depicts a recorded position trajectory over time. It is piecewise linear with rounded corners. Plot the corresponding velocity trace on the given axis. *(6 points)*

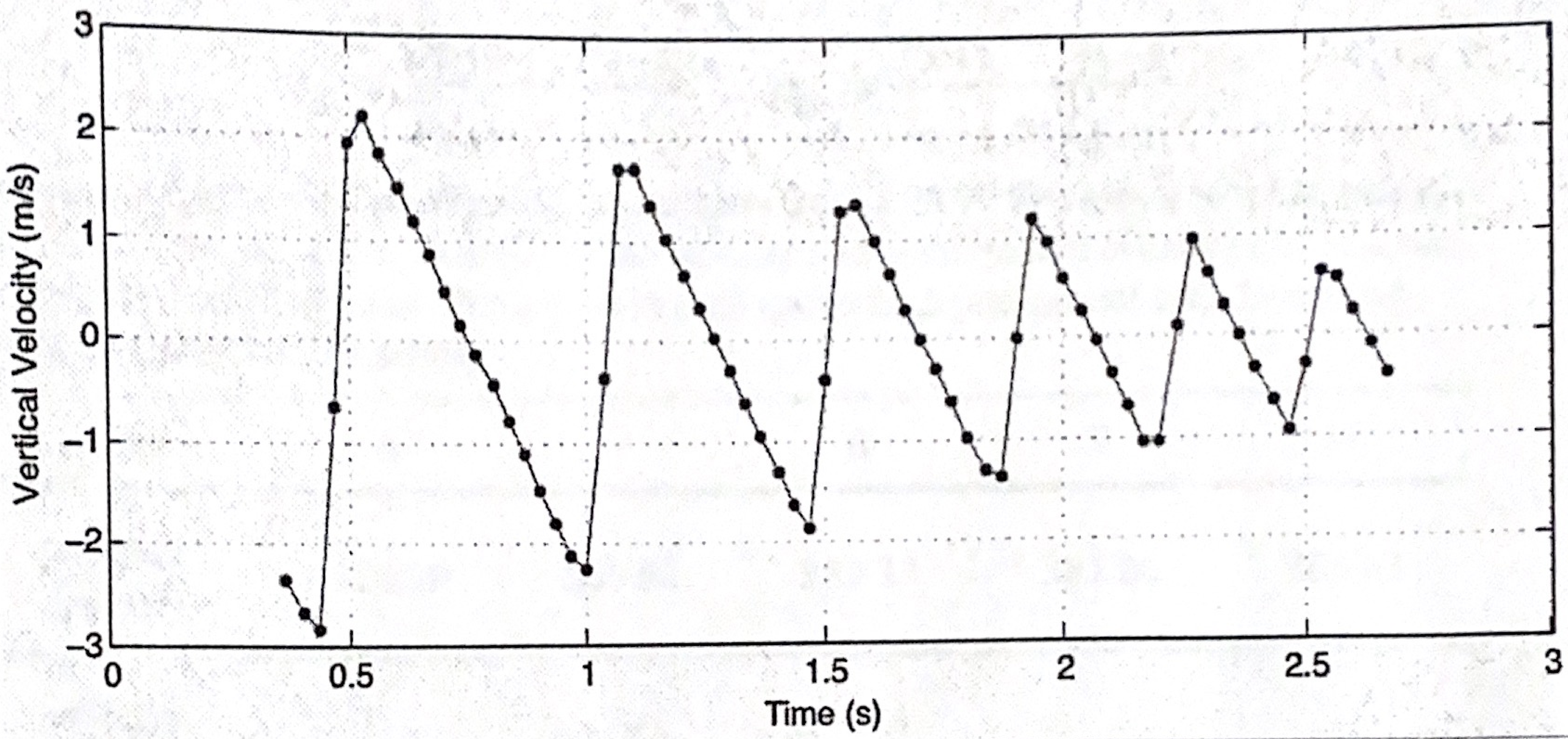


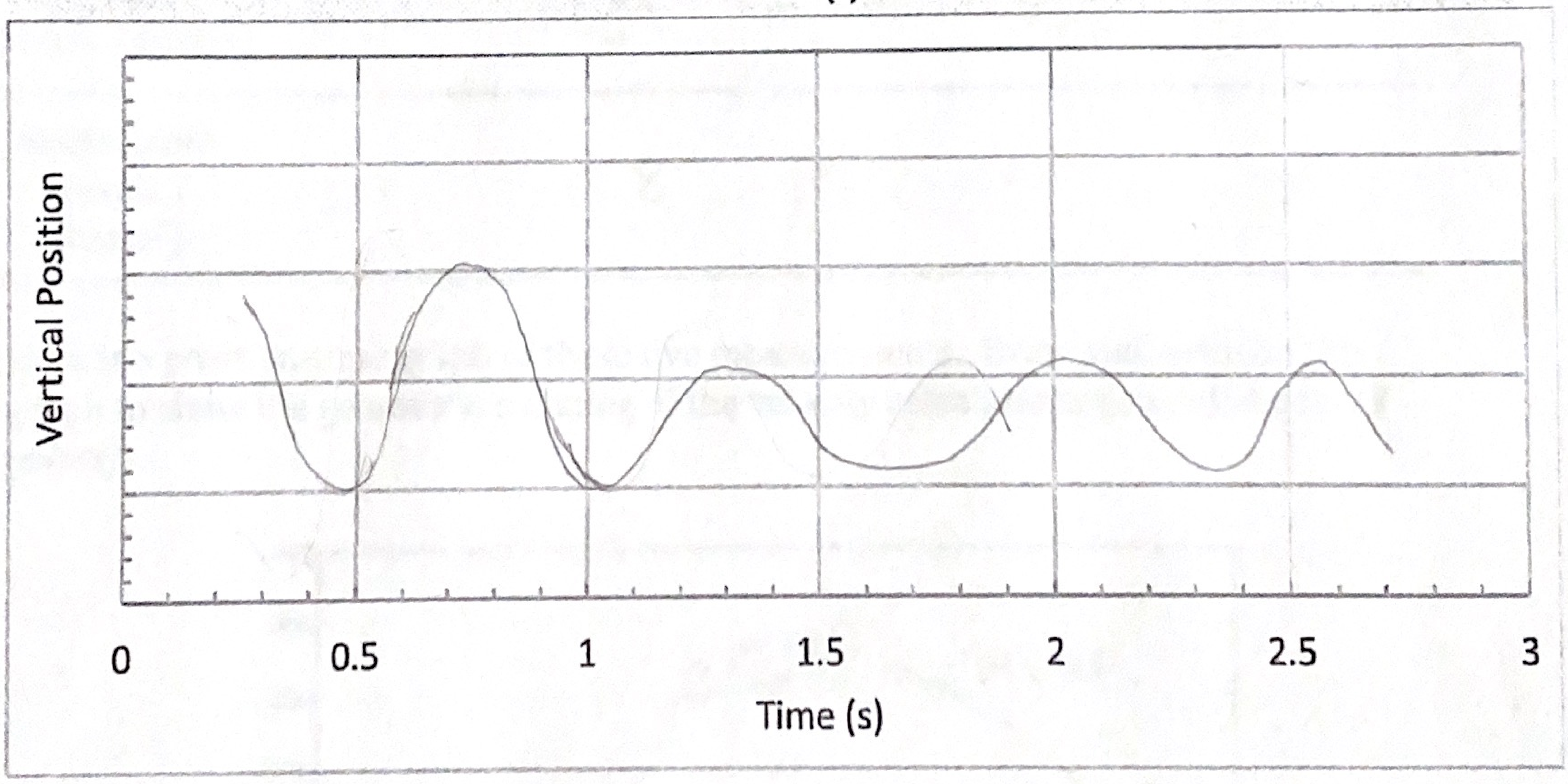


8. At what time in the above trajectory is the object experiencing the maximum acceleration magnitude? Explain briefly. (2 points)

The largest acceleration magnitude is at $t = 60$ frames because this has the largest vertical jump in the velocity-time graph, meaning this was the largest Δv per some short time t ($\frac{\Delta v}{t} = a$ was largest here).

9. This velocity-time graph was created using the same camera-based motion capture system you used in this lab, and its measurements have already converted to meters per second and seconds. The object being tracked was a lacrosse ball. Draw the position-time graph that corresponds with this velocity-time graph, without worrying about the scale for the vertical position values on the y-axis. (6 points)





10. What was the lacrosse ball doing during this movie? Explain briefly. *(2 points)*

It looks like it was undergoing simple harmonic motion but dampened so the amplitude was less each time it oscillated. It moved up and down, but slower and slower and less further from the midpoint each time.

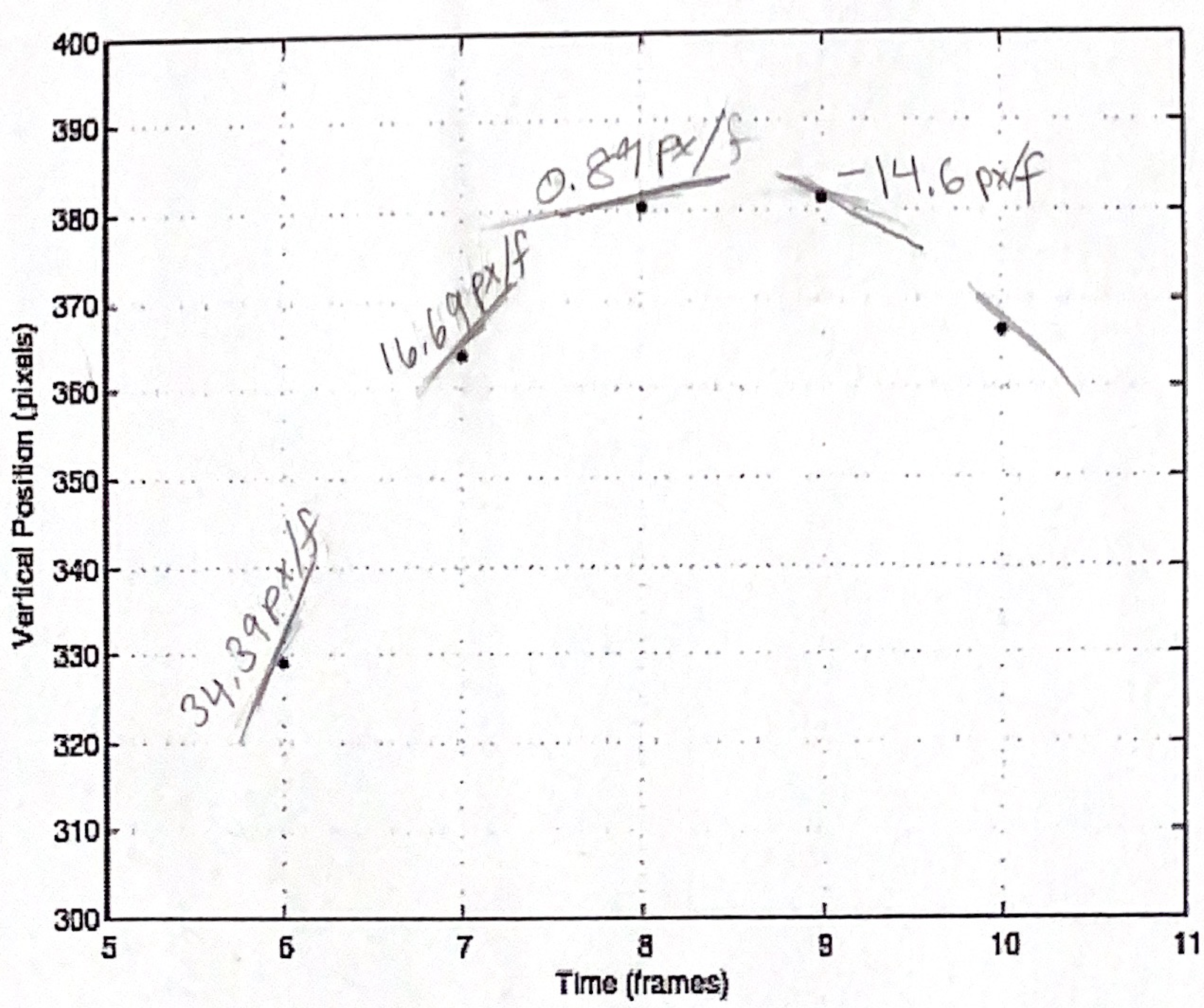
11. To obtain a velocity estimate for the *kth* frame in a video, take the measured positions and elapsed times of the following frame (number *k+1*) and the previous frame (number *k-1*). Similarly, to obtain an acceleration estimate for the *kth* frame, take the velocities and times of the following frame and the previous frame. Here are the formulas:

$$v_k = \frac{p_{k+1} - p_{k-1}}{t_{k+1} - t_{k-1}} \qquad a_k = \frac{v_{k+1} - v_{k-1}}{t_{k+1} - t_{k-1}}$$

Here are five vertical position measurements from a 29.97 FPS movie of a ball being tossed in the air. Fill in as many of the velocity and acceleration estimates as you can, using the specified units. Put a dash in each spot which you cannot calculate using given information *(4 points)*

frame	6	7	8	9	10
position (pixels)	329.29	363.68	380.37	381.26	366.63
velocity (pixels / frame)	34.39	16.69	0.89	-14.6	—
acceleration (pixels / frame^2)	-17.7	-15.8	-15.52	—	—

12. Here is a position-time graph of these five measurements. Draw and write on this graph to show the geometric meaning of the velocity calculations you did above. *(3 points)*



13. In the last exercise of the lab, you measured g, the acceleration due to gravity at Earth's surface. What two experimental factors most contributed to the discrepancy you observed between your measurement and the commonly accepted value of about 9.8 m/s^2? Explain each one carefully. *(6 points)*

- The scale for pixels to meters could have been off depending on the distance between the camera and the moving ball, which was not strictly consistent.
- The ball may have slightly bent with each bounce, dampening the motion and effectively changing the x^2 coefficient of each quadratic (each representing 1 bounce) that was used to calculate g.

14. What questions, comments, and suggestions do you have about this lab and its assignments? Your responses will help us understand what you enjoyed and how we could improve the lab for the future. Your answers to this question will not affect your grade. *(0 points)*