RGS 2012 Year 3 Physics Performance Task

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(A) Reason for selection of object

Introduction

My father is a proficient swimmer and knows many different strokes. In my opinion, the "Butterfly" stroke is the most impressive one and I would like to find out about the forces that act on the person as he does the "Butterfly" swim stroke.

Investigation Question

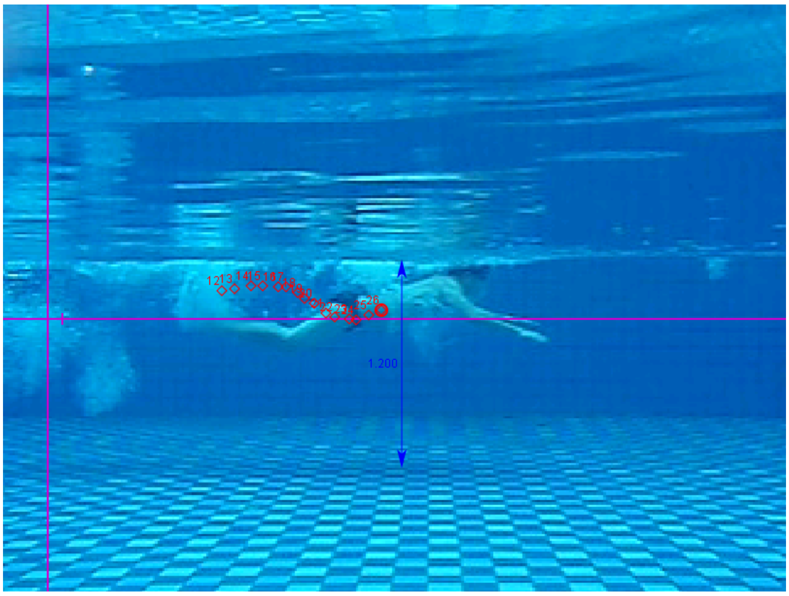
How does the forces acting upon a person change as he executes the "Butterfly" swim stroke?

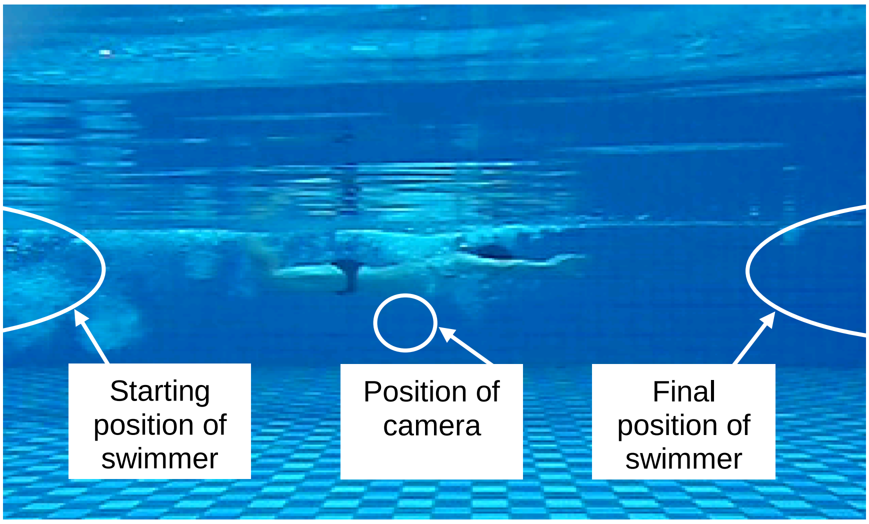
Screenshots and pictures

Right: Screenshot from Video Tracker Software

Blue line is the calibrations line. The depth of the pool, 1.2 m, is used for calibration.

Pink lines are the axis lines. Positive direction is taken as upward and rightward for vertical Y and horizontal X direction.





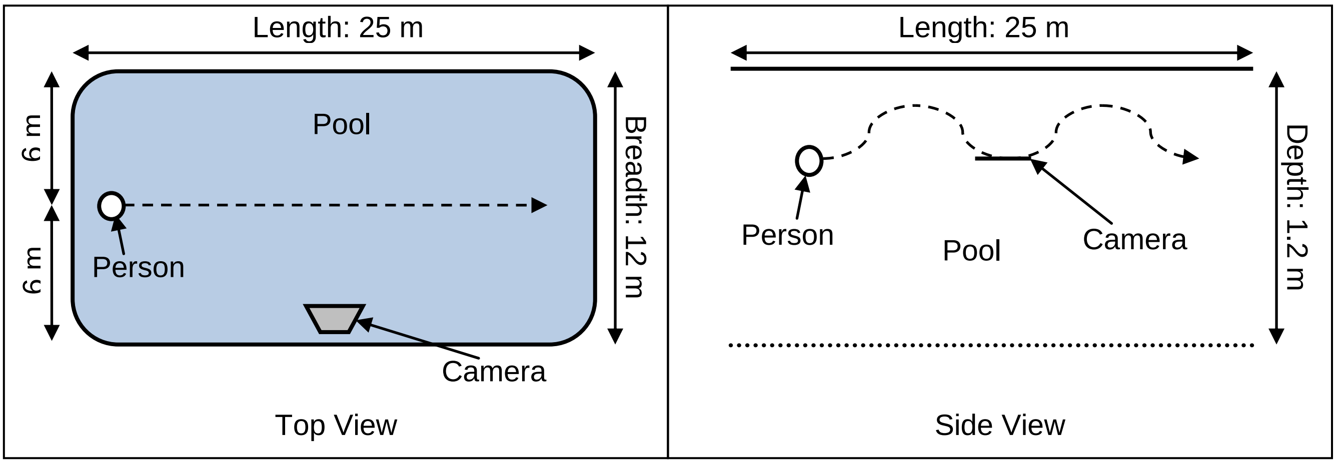
Left: Picture of Setup

Note: Camera cannot be seen in this picture as I only have one waterproof camera.

(B) Setup of the experiment and camera

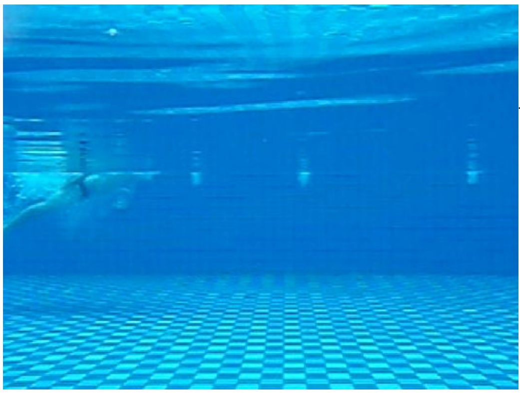
I tried many different angles – camera lens above surface, entire camera on the ledge of the pool, camera lens half submerged or camera fully submerged – to try and get the best shot. I reviewed all the videos afterwards and chose the best one, the one that gave the widest (lengthwise) view. This was the one taken with the camera fully submerged in the swimming pool.

My father was the “swimmer”. I placed the camera in the middle of the pool while my father started from the edge. My father then came into the frames and I was able to get two beautiful and full strokes, of which I then analysed with the Video Tracker software.



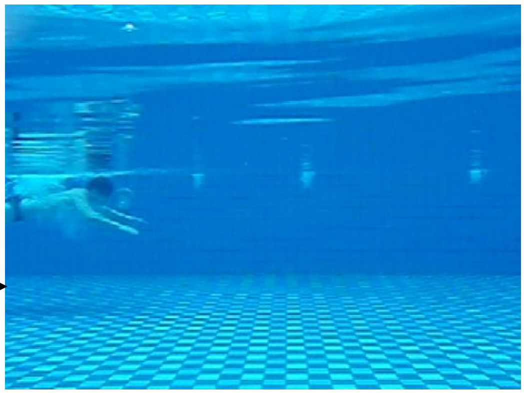
(C) Analysis of motion using graphs obtained from Video Tracker

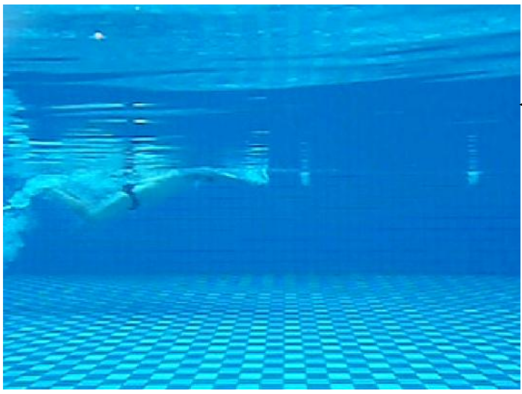
Motion broken down to sections and points for analysis



Position A:
Time = 0.00 s

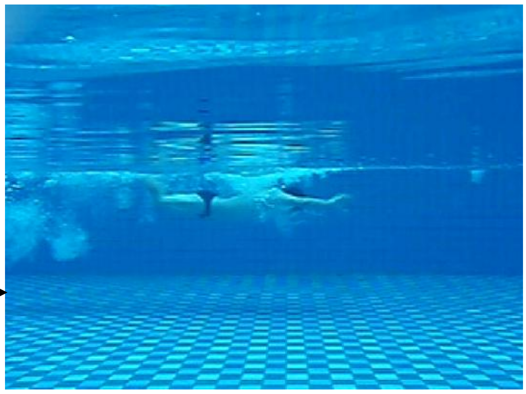
Position B:
Time = 0.40 s



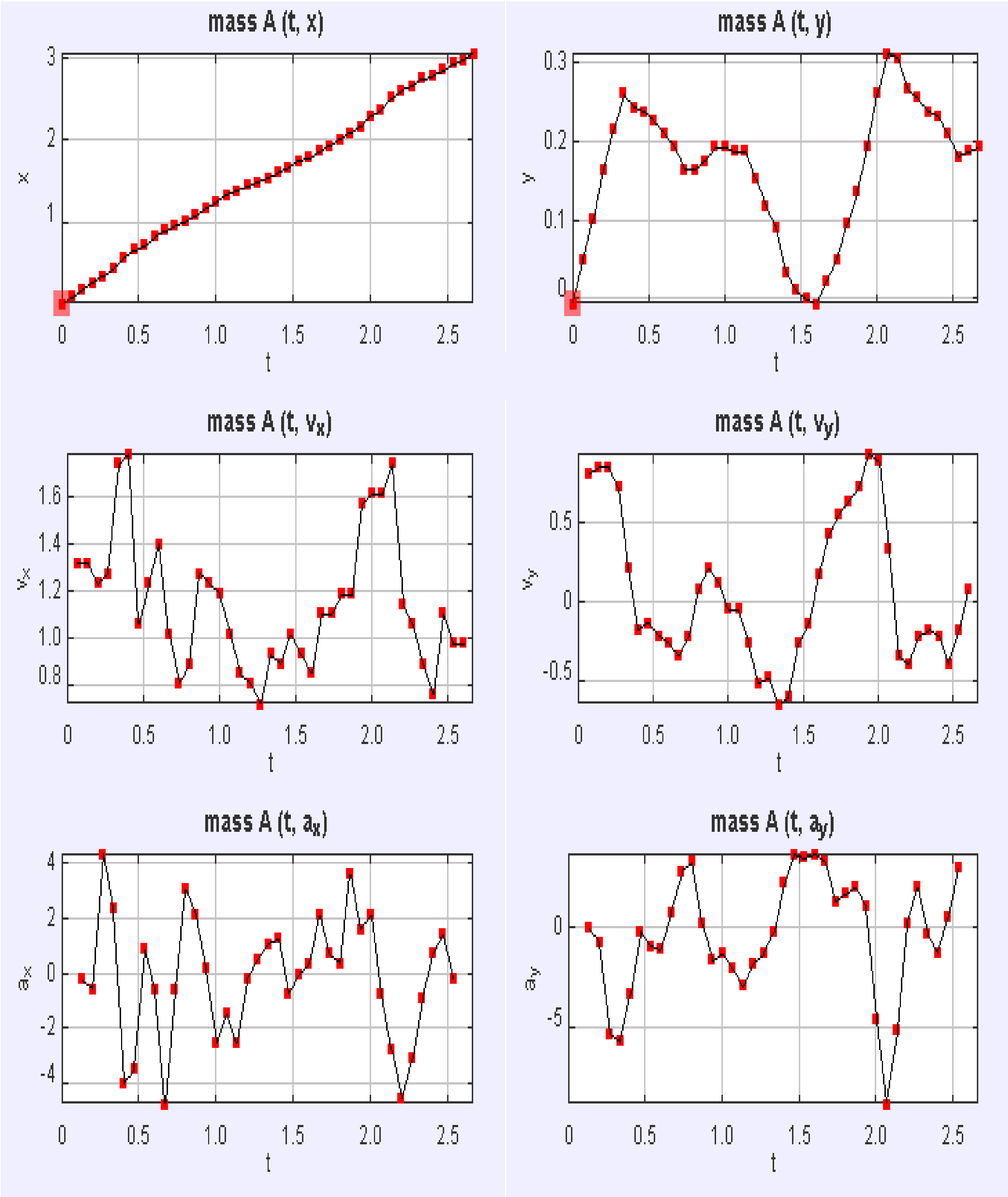


Position C:
Time = 0.80 s

Position D:
Time = 1.47 s



Screenshots of displacement-time, velocity-time and acceleration-time graphs



Position	X-direction	Y-direction
A to B	As the swimmer pulls to bring his upper body up, the general trend of the velocity-time graph shows that he experiences an increase in his horizontal speed, from 1.32 m s^{-1} to 1.78 m s^{-1}. The average horizontal acceleration is hence, 0.40 m s^{-2}.	As the swimmer pulls to bring his upper body up, the general trend of the velocity-time graph shows that he experiences a decrease in his vertical velocity, from 0.81 m s^{-1} to - 0.17 m s^{-1}. The average vertical acceleration is hence, - 2.98 m s^{-2}.
B to C	As the swimmer completes his breathing action, the general trend of the velocity-time graph shows that he has a decrease in his horizontal speed, from 1.78 m s^{-1} to 0.89 m s^{-1}. The average horizontal acceleration here is hence, - 1.33 m s^{-2}.	As the swimmer completes his breathing action, he moves his body down with an increase in his vertical velocity, from - 0.17 m s^{-1} to 0.09 m s^{-1}. The average vertical acceleration is hence, 0.18 m s^{-2}.
C to D	As the swimmer glides, the horizontal velocity increases slightly from 0.89 m s^{-1} to 1.02 m s^{-1}. The average horizontal acceleration is hence, 0.08 m s^{-2}.	As the swimmer glides with a downward tendency, the increasing vertical velocity is from 0.09 m s^{-1} to - 0.26 m s^{-1}. The average vertical acceleration, according to the acceleration-time graph, is hence, - 0.17 m s^{-2}.

Error Analysis

The centre of gravity of the swimmer at his various positions has to be estimated, around the naval area. Also, the splashing water and the sometimes blurred frames also cause me to have to estimate the swimmer's various positions. These would account for the largest source of error in this analysis. This results in a large fluctuation in the graphs, especially the acceleration-time graph. To rectify this, the average acceleration of the swimmer is calculated using the formula $a = \Delta v / \Delta t$, to minimise the effect of the random error, but it does not completely remove the error, as seen from the vertical motion from Position C to Position D.

(D) Analysis of forces on the swimmer

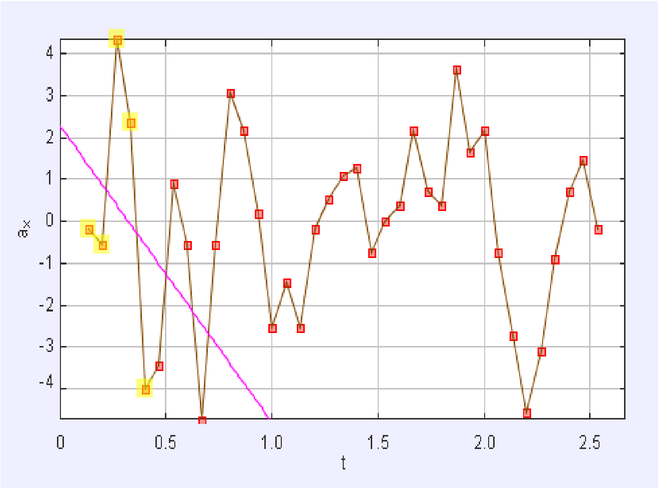
I am most interested in the forces when the swimmer pulls himself up to the surface of the water (Position B), where he takes a breath (Position C), and when he glides afterwards (Position D). The mass of the swimmer is 63 kg.

Position	X-direction	Y-direction
A to B	Since the net force of the swimmer is drag force (water resistance), the estimated drag force during this motion would be, $\Sigma F = F_d = m\,a = 63 \times 0.40 = 25.2$ N.	The weight of the swimmer is, W = mg = 63 ×10 = 630N. The maximum net force on the swimmer is, $\Sigma F = N - W = \text{m}\,a = 63 \times (-2.98) = 11.34$ N. N = 442.26 N, where N is the normal contact force which refers to the buoyancy provided by the water.
B to C	Similarly, for the motion here, $\Sigma F = F_d = m\,a = 63 \times (-1.33) = -83.79$ N.	Similarly, $\Sigma F = N - W = \text{m}\,a = 63 \times 0.18 = 11.34$ N. N = 641.34 N.
C to D	Again, for the gliding motion, $\Sigma F = F_d = m\,a = 63 \times 0.08 = 5.04$ N.	Again, W = mg = 63 ×10 = 630N $\Sigma F = N - W = \text{m}\,a = 63 \times (-0.17) = -10.71$ N. N = 619.29 N.

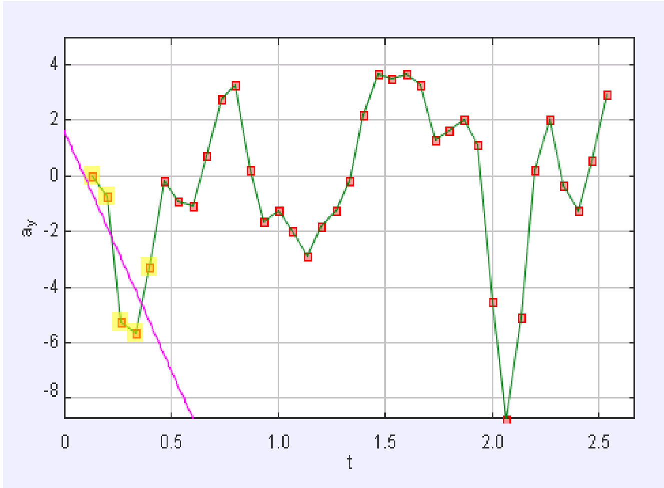
- END -

Appendix

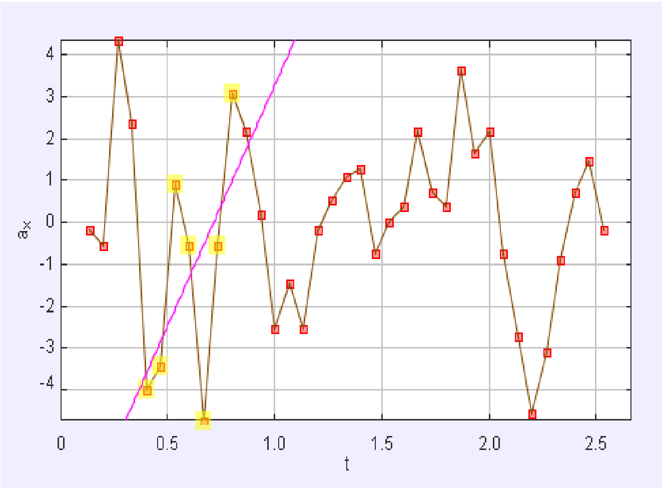
Line of best fit to find average acceleration.



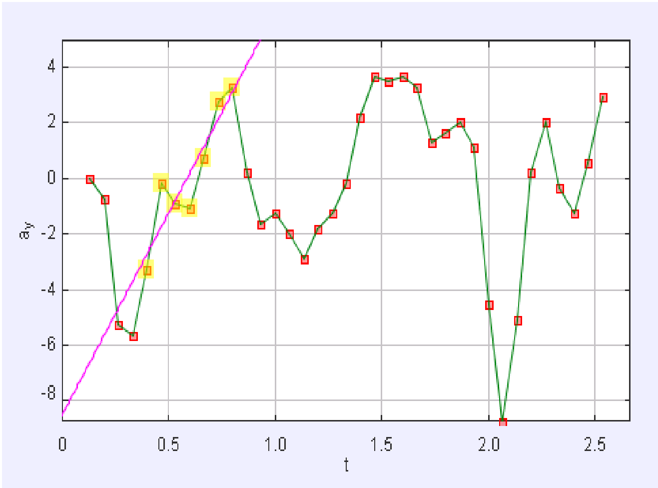
Position A to Position B (Horizontal Motion)



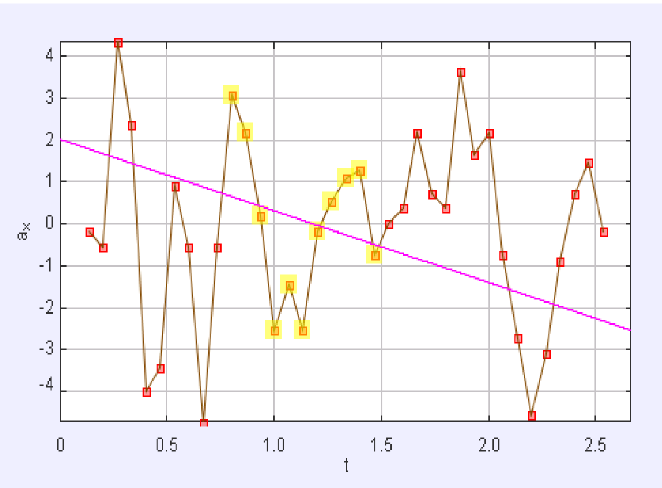
Position A to Position B (Vertical Motion)



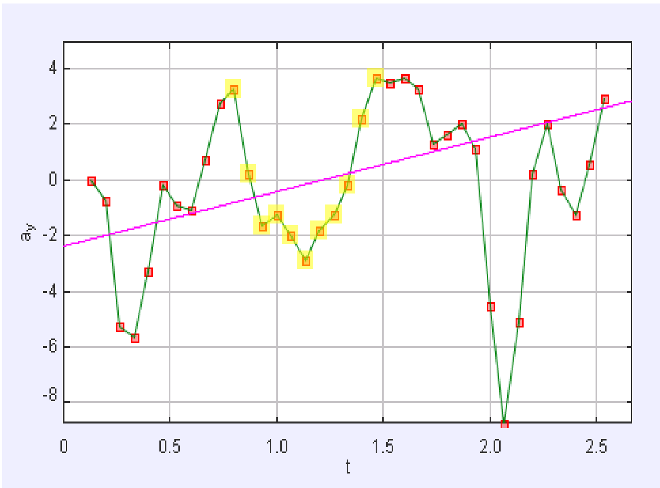
Position B to Position C (Horizontal Motion)



Position B to Position C (Vertical Motion)



Position C to Position D (Horizontal Motion)



Position C to Position D (Vertical Motion)