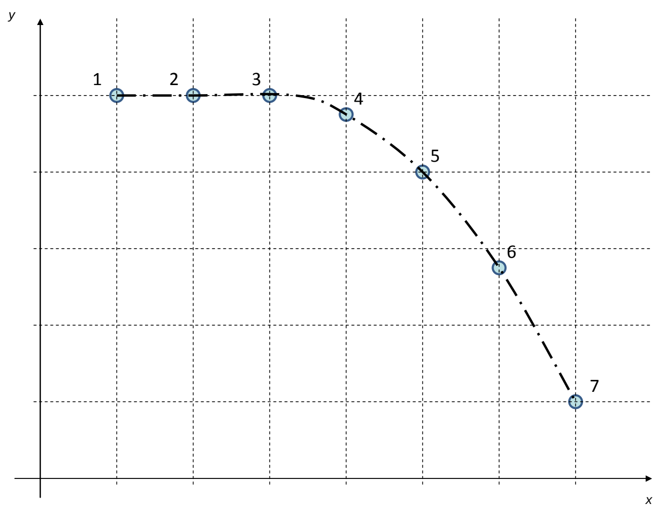
Physics 172 – Recitation 02

Spring 2012

You will find more information about the topics covered in today's problems in chapter 1 and in sections 2.1 through 2.3 of chapter 2 of the text.

Problem 1. A child is playing with a low-friction toy car on the balcony of her mother's apartment. The figure below shows the car's position at a sequence of equally spaced times separated by 0.226 seconds. It shows the car initially running in the *x* direction, under the guardrail and off the edge of the balcony at time t_3. The *x*-axis runs along the level ground below the balcony. The *y*-axis runs vertically upward and the *z*-axis points toward you. The gridlines shown are 1 meter apart.



a) What are the components of the vectors $\Delta\vec{r}_{21}$ and $\Delta\vec{r}_{32}$ representing the displacement of the toy car as it rolls across the balcony? Don't forget to show the units of the components of these and the other vectors you work with today.

b) What are the components of the toy car's average velocity vector between times t_1 and t_2? Between t_2 and t_3? Explain how your answers are consistent with Newton's first law and what you know about the interactions between the car and its surroundings as it rolls across the balcony.

c) What is the toy car's speed as it rolls across the balcony? What are the components of the unit vector $\hat{v}$ representing the direction of the toy car's velocity as it rolls across the balcony? What are the components of the toy car's instantaneous velocity at t_3 just as it leaves the edge of the balcony? Save this result. You will need it later.

[Checkpoint 1]

d) What are the components of the toy car's average velocity vector between times t_3 and t_4? Between t_3 and t_5? Between t_3 and t_6? Explain how your answers are consistent with Newton's first law and what you know about the interactions between the car and its surroundings as it flies through the air.

e) Sketch the figure showing the sequence of the toy car's positions on your white board, and add arrows representing the instantaneous velocity of the car at time t_3 and the average velocities you computed in part d). Draw all four of the vectors with their tails at the car's position at t_3. Because the units of velocity (meters/second) are different from the units of displacement (meters), you must choose a scale factor in order to draw these velocity vectors on your picture. Of course, you use the same scale factor for all velocity vectors.

Explain briefly how your figure is consistent with the text's statement that

i) The direction of the instantaneous velocity of an object is tangent to its path.

ii) Using smaller time intervals to calculate an object's average velocity gives better estimates of its instantaneous velocity.

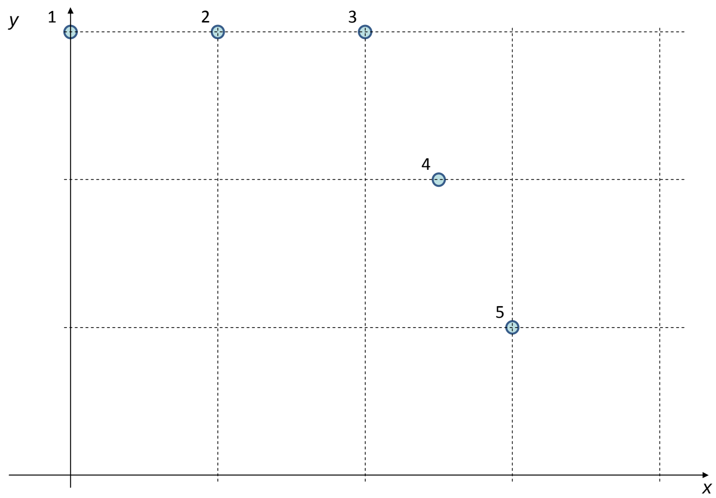
f) What are the components of the toy car's average velocity vector between times t_4 and t_5? Draw an arrow representing this velocity as an estimate of the car's instantaneous velocity at time t_4 with its tail at the car's position at t_4.

What are the components of the toy car's average velocity vector between times t_5 and t_6? Draw an arrow representing this velocity as an estimate of the car's instantaneous velocity at time t_5 with its tail at the car's position at t_5.

Use the velocity components you calculated to estimate the components of the car's average acceleration vector $\vec{a}_{avg} = \Delta\vec{v} / \Delta t$ during the interval between t_4 and t_5. Explain how you would use the arrows you drew to represent the car's velocity at t_4 and at t_5 to estimate the components of the car's average acceleration using your drawing. Verify the components calculated this way are consistent with the components you calculated directly.

[Checkpoint 2]

Problem 2. The figure on the next page shows positions of a hockey puck on the horizontal ice surface of a hockey rink at a sequence of times t_1, t_2, t_3, t_4 and t_5 that are spaced 0.1 seconds apart. The *x*-axis of the coordinate system shown runs along the length of the rink, its *y* axis runs across the rink and its *z* axis points up toward you. The spacing between the gridlines shown is 3 meters. At time t_3 a hockey player (not shown) hits the puck with their hockey stick.



Transfer a sketch of this drawing to your white board, and work with your partners to answer these questions.

a) Use the components representing the puck's displacement between t_2 and t_3 to compute its average velocity vector during that interval. Use them as estimates of the components of the puck's instantaneous velocity at t_2.

Compute the components of the puck's average velocity between t_3 and t_4. Use them as estimates of the components of the puck's instantaneous velocity at t_3, just after the player hits the puck with his hockey stick.

b) The puck's mass is 0.16 kg. Use this fact and your results from part a) to estimate the components of the puck's momentum at times t_2 and t_3. Verify explicitly that the puck's γ factor has a value very close to 1 at both times. Draw an arrow representing each momentum vector with its tail at the corresponding position of the puck. Again, you must choose a scale factor to represent these vectors with units of kg m / sec on your figure and use the same scale factor for all momentum vectors.

c) Use your preceding results to estimate the components of the change in the puck's momentum $\Delta\vec{p}$ during the interval from t_2 and t_3. Verify that a graphical estimate of these components from your figure is consistent the results you calculate directly.

d) This change of momentum actually occurs during a very short time interval $\Delta t_c = 0.005$ seconds when the player's hockey stick is in contact with the puck. Assume that the force exerted on the puck by the stick is constant during that interval. Apply the momentum principle to the system consisting of just the puck to obtain a relationship between the change in the puck's momentum and the components of the force exerted on the puck by the stick, an object in the puck's surroundings. What are the components of this force? How would you describe the relationship between the direction of this force and the direction of $\Delta\vec{p}$?

[Checkpoint 3]