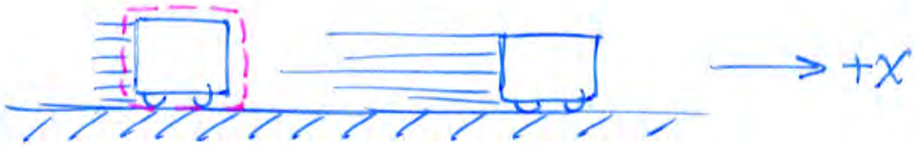
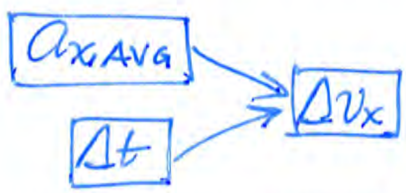
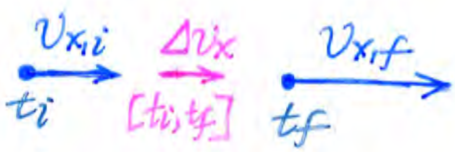
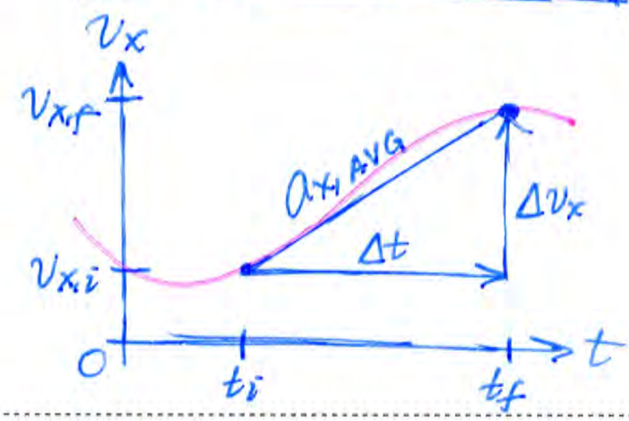
K5

Title		Average x-acceleration
Ingredients	Sketch	
	At/Through	$[t_i, t_f]$
	Owner	System; Frame
	Quantity	Change in x-velocity; Average x-acceleration; Elapsed duration
	Variable	Δv_x; $a_{x,AVG}$; Δt
	Giver	
Recipe	Diagram the relationship	
	Graphically present quantities	Velocity-change vector  On v_x-t plot: Slope of secant line 
	Mathematical relationship	$a_{x,AVG} \Delta t = \Delta v_x$; $a_{x,AVG} = \frac{\Delta v_x}{\Delta t}$

Recipe number **K5**: The **title** of this recipe sheet is "**average x-acceleration**".

The top half of this sheet consists of an "**Ingredients**" section with a row labeled "Sketch", a row labeled "At/Through", a row labeled "Owner", a row labeled "Quantity", a row labeled "Variable", and a row labeled "Giver." In this sheet, the row labeled "Giver" isn't used.

For the "Sketch", draw two snapshots showing a cart moving toward the right across a firm surface. Draw trailing motion-blur streaks or so-called "whooshies" to emphasize instantaneous motion in each snapshot, with longer whooshies trailing the second snapshot, the one on the right. Draw a dashed bubble around the earlier snapshot of the cart, at the left, to indicate that the cart is the so-called "System". Draw an arrow labeled +x to indicate that the positive-x direction points to the right.

In the rows of the "Ingredients" section other than the row for the sketch, document the following relationships, using flowchart paths, if helpful: There are two "Owners": one is the "System", and the other is the "Frame". For the interval from initial time t_i (t-sub-i) to final time t_f (t-sub-f), the system has both the "Quantity" called "Chang in x-velocity" denoted by the "Variable" (Delta v-sub-x) and the "Quantity" called "Average x-acceleration" denoted by the "Variable" $a_{x,\mathrm{AVG}}$ (a-sub-x-average). Also for the same interval from initial time t_i (t-sub-i) to final time t_f (t-sub-f), the "Frame", meaning the collection of rulers and clocks used to make measurements and referred together as the "frame of reference", has the "Quantity" called "Elapsed duration" denoted by the "Variable" (Delta t).

The bottom half of this sheet consists of a "**Recipe**" section with a row labeled "Diagram the relationship", a row labeled "Graphically present quantities", and a row labeled "Mathematical relationship".

In the row labeled, "Diagram the relationship", draw a flowchart arrow showing that average x-acceleration $a_{x,\mathrm{AVG}}$ (a-sub-x-average) contributes to the change in x-velocity (Delta v-sub-x). Draw another arrow showing that elapsed duration (Delta t) also contributes to the change in x-velocity (Delta v-sub-x). Recite a story: "Greater average x-acceleration through a given elapsed duration results in a greater change in x-velocity, but even if the average x-acceleration remained unchanged, simply allowing that average x-acceleration to apply through a longer elapsed duration would also result in a greater change in x-velocity."

The row labeled "Graphically present quantities" will be divided into two sections.

In the first section, write the title "Velocity-change vector". Draw two dots from a breadcrumb motion diagram representing snapshot locations of the cart in the "Sketch". Leave some space between the dots. Underneath the first dot (the one at the left), write the label t_i (t-sub-i), and underneath the second dot (the one at the right), write the label t_f (t-sub-f). Draw an initial velocity vector with its tail attached to the first dot (the one at the left) and its head pointing toward the right. Label this velocity vector with the initial x-velocity $v_{x,i}$ (v-sub-x-i). Draw a final velocity vector with its tail attached to the second dot (the one at the right) and its head pointing toward the right. Make this velocity vector longer than the initial velocity vector. Label this velocity vector with the final x-velocity $v_{x,f}$ (v-sub-x-f). In the space between the initial velocity vector and the second dot, draw an arrow pointing to the right. Underneath this change-in-velocity vector, write the label $[t_i, t_f]$ (open bracket t-sub-i comma t-sub-f close bracket. Label the change-in-velocity vector as the change in x-velocity (Delta v-sub-x). Scale the change-in-velocity vector so that when the initial velocity vector and the change-in-velocity vector are stacked together head-to-tail, their combined size and direction match the size and direction of the final velocity vector.

In the second section of the "Graphically present quantities" row, write the title "On v_x-t (v-sub-x-t) plot: Slope of secant line". Create an axis system with x-velocity v_x (v-sub-x) on the vertical axis and time t on the horizontal axis. Draw a smooth plot with some variety of v_x (v-sub-x) values (the exact shape isn't very important). Draw two dots on the plot, with one more toward the left and lower on the page and the second more toward the right and higher on the page. For the dot on the left, draw corresponding tickmarks labeling initial time t_i (t-sub-i) on the t axis and initial x-velocity $v_{x,i}$ (v-sub-x-i) on the v_x (v-sub-x) axis. For the dot on the right, draw corresponding tickmarks labeling final time t_f (t-sub-f) on the t axis and final x-velocity $v_{x,f}$ (v-sub-x-f) on the v_x (v-sub-x) axis. Draw a slanted segment with the dots as endpoints. Use this slanted segment as the hypotenuse of a right triangle, with a horizontal leg represented by an arrow pointing to the right labeled with the elapsed duration (Delta t) and a vertical leg represented by an arrow pointing up labeled with the change in x-velocity (Delta v-sub-x). In slanted writing, label the hypotenuse of the right triangle $a_{x,\mathrm{AVG}}$ (a-sub-x-average).

In the row labeled, "Mathematical relationship", write (a-sub-x-average times Delta t = Delta v-sub-x) and (a-sub-x-average equals Delta v-sub-x divided by Delta t).