UNIT II: PARTICLE MOVING WITH CONSTANT VELOCITY

Instructional goals

1. Reference frame, position and trajectory
   Choose origin and positive direction for a system
   Define motion relative to frame of reference
   Distinguish between vectorial and scalar concepts
   (displacement vs distance, velocity vs speed)

2. Particle Model
   Kinematical properties (position and velocity) and laws of motion
   Derive the following relationships from position vs time graphs

$$\Delta x = x_f - x_0$$

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

$$x = \bar{v}t + x_0$$

$$\Delta x = \bar{v}t$$

3. Multiple representations of behavior
   Introduce use of motion map and vectors
   Relate graphical, algebraic and diagrammatic representations.

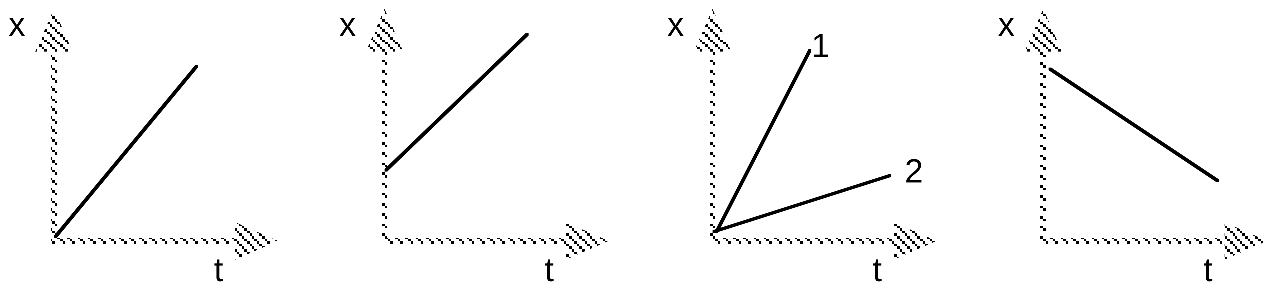
4. Dimensions and units
   Use appropriate units for kinematical properties
   Dimensional analysis

5. Software
   Intro to *Conceptual Kinematic Tutorial* (PAS)

Overview

1. It is important to describe motion in terms of *position* and time, rather than distance. Position is much less ambiguous than distance (sometimes regarded as the path length, sometimes as displacement). Some authors use 's' to describe this variable; we prefer 'x' for horizontal motion (and 'y' when the motion is vertical). We advise against the use of 'd'. When it comes time to discuss the slope of the position-time graph, the definition for velocity, $v = \frac{\Delta x}{\Delta t}$, naturally arises. Change in position is superior to change in distance; the latter is a difference of differences. Change in position is the definition of *displacement,* the quantity that helps distinguish velocity from speed. Displacement can be (+) or (-), distance is by definition (+).

2. When discussing the meaning of the graphs, be sure to use a wide variety of examples.

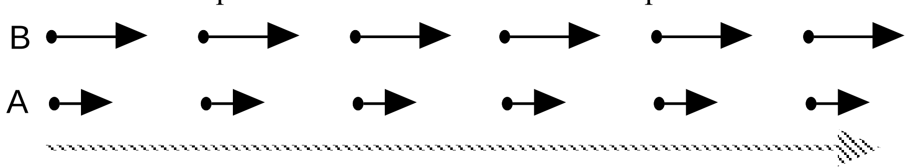


   Induce the students to describe the motion in full detail (e.g., the object starts somewhere to the right of the origin and moves to the left at constant speed).

3. Using an enlargement of one of their graphs, have the students manually calculate the slope and compare to the value obtained by GA. Students have been conditioned to think of slope only as "rise over run" or ˘y over ˘x.

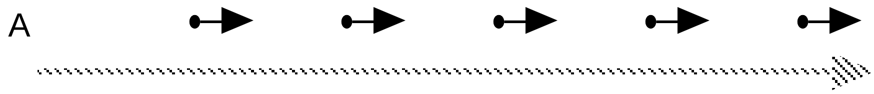
4. Make sure that they have a thorough grasp of the relationship between slope and velocity. The answer "1's slope is greater than 2's" is not a guarantee of understanding. It would be profitable to have students model the behavior of the object represented by a variety of graphs. If you have an ultrasonic motion detector, this is great fun!

5. Work on making motion maps to represent the position-time behavior of moving objects. Make sure that these semi-quantitative devices are faithful representations.

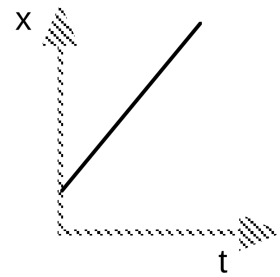


   Students have been known to draw the motion map above and state that B was moving faster than A because the velocity vectors were longer.

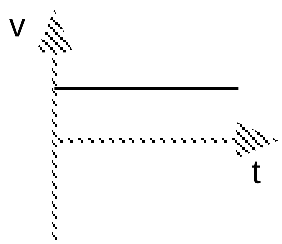
6. Make sure that students can, given an algebraic statement, an **x** vs **t** graph, or a motion map, recreate the other two representations.

Given: 

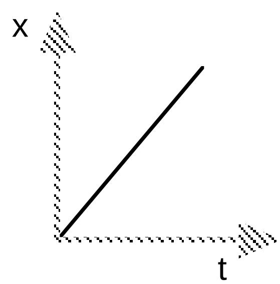
They should be able to write: $x = vt + x_0$ and draw

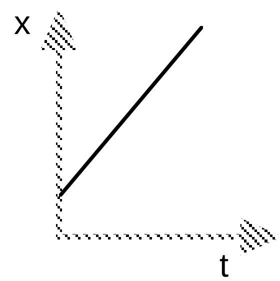


7. Be sure to make the connection between **x** vs **t** graphs and **v** vs **t** graphs. "Stacking" the curves helps to illustrate this relationship.

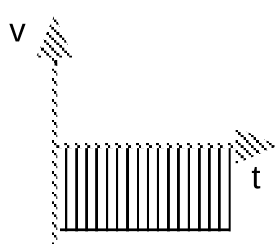


Make the point that the **v** vs **t** graph yields no information about starting point. The **v** vs **t** graph at left could represent either of the **x** vs **t** graphs below.





8. Make the point that the area under a **v** vs **t** graph represents the displacement, ˇx of the object. This could be both (+) and (-). Avoid always using the trivial case.



Sequence

1. Battery-powered vehicle lab
2. Worksheet 1
3. Worksheet 2
4. Quiz
5. Worksheet 3
6. Reading: Motion maps
7. Worksheet 4
8. Worksheet 5
9. Review
10. Test

Instructional notes
Battery-powered vehicle lab

Apparatus

any slow-moving battery powered toy vehicle
stop watches
meter sticks
masking tape
Graphical Analysis

Pre-lab discussion

¥ Let the vehicle move across table and ask for observations. List observations and then ask which items are quantifiable. Lead them to observe that the tractor moves at constant speed; i.e., that it travels equal distances in equal time intervals.

¥ The dependent variable is position (x). Emphasize that we are dealing with position, not displacement or distance traveled.

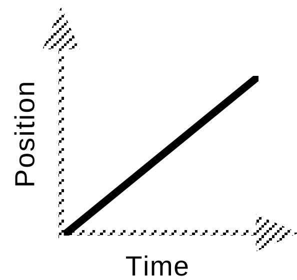
¥ The independent variable is time (t). Emphasize time as a *clock reading* and not an interval of time. (Why make time independent? Because when time is graphed on the horizontal axis the slope will be equivalent to velocity.)

Lab performance notes

¥ Stopwatches and toy tractors are easier to use than "stomper" cars and photogates. (Honors classes may be able to handle use of photogates at this stage.)

¥ However you choose to have the students collect the data, they should be reminded to perform multiple trials with at least 6 data pairs/trial. Averaging the values of position helps them develop a sense of the precision they should carry through the analysis. Otherwise they are guilty of adhering to Lillenthal's Laws:

1- If reproducibility is a problem, conduct only 1 test.
2- If a straight line plot is required, collect only two data points.



Post-lab discussion

¥ Focus discussion on the position versus time relationship.

¥ Use slope-intercept form to write equation of line (e.g. $x = \left(0.85 \, {}^{m}\!/_{s}\right) t + 0.12m$).

¥ Discuss the slope of the line as being a constant. Introduce the label units of slope (m/s).

¥ Identify v (velocity) as the slope in the slope-intercept equation.

¥ Discuss the vertical intercept and the "5% rule-of-thumb". In most cases, the intercept is negligible.

¥ From specific equation, write general mathematical model $\Delta x = \bar{v} t$. Discuss displacement (˜x) when initial position is not zero.