Unit 1 – Module 2

Interpreting motion graphs activity (Walk the Line Activity)

RATIONALE

Students should be able to look at a x(t) graph and visualize the motion indicated by the various properties of the graph. This could be considered a separate skill from making the graph or doing numerical analysis of a graph, in that it should happen almost instantaneously and will serve as a useful tool when entering into an analysis of accelerated motion, v(t) and even a(t) graphs. Students should be looking for the linearity of the graph, the magnitude of the slope of the graph, the sign of the slope of the graph, the y-intercept of the graph, the x- intercept of the graph and become aware of instances where the graph has a change in slope. All of these attributes should be connected to the actual motion of an object or, in this case, a person.

The activity is presented here as something for the entire class to view as a whole. The expectation is that the teacher selects students according to their abilities and personalities so that every student will be at once challenged and successful as they interpret the graphs. Incorrect interpretations are often more instructive than successful attempts, so the teacher must remain aware of teaching moments as they arise from the class’ comments and the participating students actions.

As an activity that is “performed” in front of the class, there are numerous pedagogical facets that a teacher should be aware of, beyond the basic physics. Many students are reluctant to do anything in front of peers, particularly when there is the possibility of being wrong or of looking silly or ignorant. The teacher should make sure that the challenge level of the task is appropriate to the level of the student – slightly trickier than they think they can solve, but comprehensible once they have made a few attempts.

PRIOR KNOWLEDGE AND SKILLS

* how to make position vs. time graphs for objects moving at a constant velocity, based on data tables
* basic terms for graphing, including slope, x and y axis, rise, run
* basic terms for motion, including speed, origin, reference frame, direction

CE’s AND PE’s

*21. Interpret a position vs. time graph to find the location of an object at a particular time*

*22. Interpret a position vs. time graph to find the time at which an object reaches a particular location*

*23. Recognize the correlation between the slope of a line on a position vs. time graph and the speed of an object*

* *Since the slope is the change in position versus the change in time, which is the speed, the greater the slope the greater the speed*

*24. Describe the motion of an object based on the shape (linear or curved) of the position vs. time graph*

* *Linear motion is constant motion - the slope is constant*
* *Curved motion is accelerated motion - the slope in not constant*

*25. Differentiate between instantaneous and average velocity*

*26. Recognize that the position vs. time relationship for an accelerating object is different than that for an object with unchanging velocity*

27. Know the shape of a position vs. time graph for an accelerating object

* Accelerated motion graphs are curved not linear

PHYSICS CONVENTIONS

* time is usually on the x-axis of a graph vs position, velocity, acceleration, etc
* when possible, it makes sense to call t=0 the beginning of the experiment/data collection time
* position vs time graphs show the movement of an object along a single axis
* positive and negative values are dictated by the reference frame, not necessarily the object that is moving (ie. negative motion is not the same thing as going backwards)

STUDENT GROUPING

The entire class watches, though only one student at a time is actively enacting the graph. It is up to the teacher to determine the level of student participation in the coaching/correcting offered by the observing students. However, when there is active student input from the audience the teacher has the opportunity to gauge student understanding and uncover student misconceptions that might go unnoticed if no comments are allowed.

MATERIALS

Overhead LCD projector and Powerpoint show (option #1)

Masking tape and chalkboard (option #2)

Space for students to see the screen/board as well as space to walk and run in a straight line in both directions

TIMELINE (about 35 minutes)

2-3 minutes – lecture, recalling the fact that the movement of an object can be captured in a variety of ways, including graphs of an object’s position as time goes on.

20-30 minutes – individual students called to replicate the motion represented by various graphs. As the complexity of the graphs increases, different aspects of x(t) graphs become significant.

• The teacher should show the set of axis, (the first powerpoint slide, if LCD is available) and point out that it is identical to the axis used when making graphs of position and time for the ticker-timer activity (or equivalent graphing experience). If no LCD is available, then a crude set of axis can be made on the chalkboard with 2 pieces of masking tape. This will allow rapid erasing of past graphs, and the quick introduction of new graphs while encouraging students to imagine that there is no scale change from one graph to the next. The x-axis should be placed at mid-height on the board, to give space for action in the negative region of the graph and the axis should be clearly labeled.

• Display the first graph (graph A) and ask a student to come to the front of the room and recreate the motion indicated by the graph. The slides have letter titles so that the teacher can keep track of what graphs will be upcoming and call an appropriate student for the challenge.

• Continue through the graphs, asking the class whether the re-creation was accurate or if there were inconsistencies. There may be some instances when alternative interpretations are valid and those should be demonstrated, as well.

• It is useful to, on occasion, ask the student to describe their motion immediately after they move, so that they make clear for the rest of the class what aspects of the graph they considered to be important and how those were manifest in their actions.

• Whenever possible, students should verbalize the important considerations, rather than have the rules imposed by the teacher. (ie, where, in the classroom, is the origin? Does the scale change from one graph to another? What direction is positive? When is the student “starting” the demonstration? When have they finished?)

|  |  |  |
| --- | --- | --- |
| **Stage of activity** | **What the students should do** | **Student mistakes** |
| Graph A | Walk at a constant velocity | Do not start at the origin |
| Possible teacher responses:  At the outset the class will not recognize the significance of the location of the origin in the classroom itself. If the first student mentions starting at a particular location, then the origin should be made explicit to the rest of the class, although the need for an origin becomes clear in graph C. In either event, the origin should be placed in a location that has sufficient room in both directions for walking and running. (ie, not at a wall or in a corner) | | |
| Graph A | Walk at a constant velocity along the floor | believe an upwards sloping graph indicates upward sloping movement |
| Possible teacher responses:  After a successful recreation by the student, ask why the student did not try to climb the walls, get taller, walk up a ramp, etc. This misconception (that the graph indicates the PATH of the object’s motion through space) is persistent, and this may be the first time that many students realize that it is a potential hazard. The teacher may also take this opportunity to clarify for the class the established (positive) direction of the measured displacement. The sign of the displacement is best left ambiguous until graph F. | | |
| Graph B | Walk/run at a constant velocity, but faster than the previous student | Repeat the same action as the previous student |
| Possible teacher responses:  A discussion of scale is appropriate here. The lack of numbers along the axis emphasizes the broad interpretations we are attempting. However, once the slope for walking speed has been established, we can assume that subsequent recreations rely on the same scales along the axis. | | |
| Graph C | Walking in positive direction, starting “behind” the origin (in negative territory) | Walk backwards, walk in the negative direction |
| Possible teacher responses:  Because the graph shows what happens at various instances in time, the graph is almost a story. By holding up a meter stick vertically at the origin and slowly sliding it to the right, a correct interpretation of the graph emerges: start in negative territory, get closer to the origin, pass the origin, move away from the origin. With an LCD projector, the teacher can obscure the graph with a hand, then slowly reveal the graph in real-time as the student recreates the motion. | | |

|  |  |  |
| --- | --- | --- |
| Graph D | Start at a location in the positive space, then move at a constant walking speed in the positive direction | walk into the positive region and then continue in the positive direction |
| Possible teacher responses:  Can point out the need for students to indicate when t=0 is taking place. Although there is no graph in the negative TIME region, it does not mean that the object did not exist, it simply indicates that we, as physics students, are not interested in the object during that time. It will be increasingly important for students to recognize WHEN mathematical or graphical modeling begins or ends in order to use the models accurately and effectively. It may be useful for students to say “start” and “end” when they are recreating the graphs. | | |
| Graph E | Stand in the positive region | move |
| Possible teacher responses:  Read the graph at specific points in time to locate the object and note that the location does not change as time goes on. There is a strong inclination to say that whenever the graph is “straight” then the object is standing still. Point out that ALL of the graphs we have looked at so far are straight, the difference is that this one is straight and HORIZONTAL. | | |
| Graph F | Student should start at the origin and move into the negative region | Walk into the positive region, backwards |
| Possible teacher responses:  In most cases, the rest of the class will point out the correct motion, and the active student will then recreate the graph by walking backwards from the origin, which is correct. There may be some students who recognize that the way the object is facing is not relevant, in which case they should demonstrate to the class another way to recreate the graph – by walking forwards into the negative region of space. | | |
| Graph G | Start in negative, walk/run quickly in negative direction |  |
| Possible teacher responses:  Students by now have managed to catch on and this graph merely puts together many of the aspects of x(t) graph discussed previously. If desired, other graphs with similar variations (linear, uniform motion) can be created to re-enforce concepts so that all students can participate. | | |
| Graph H | Student should walk/run away from the origin, then return past the origin | Continue moving in the positive direction, merely changing their speed |
| Possible teacher responses:  Point out that more complex motions can be represented on the same graph, although there are difficulties. What is the slope of the graph? Where all previous examples showed a single slope and therefore a single speed, this one is not uniform, though it is linear in certain parts. Simple questions like “how far will you go in 3 seconds?” become more difficult because we are no longer analyzing a single, straight line. It will become increasingly important that students recognize when to break up complex motion into simpler pieces for numerical analysis. | | |

|  |  |  |
| --- | --- | --- |
| Graph I | Start in positive region, move into negative, pause, then run into positive region |  |
| Possible teacher responses:  Students should be comfortable with this graph at this point, simply stringing together different uniform motions. It is a good idea to have the student verbalize the difference between the initial walk speed vs the later run speed, discernable from the differing slopes. | | |
| Graph J | Student starts at the origin moves quickly into the positive region and slows to a stop |  |
| Possible teacher responses:  Encourage students to verbalize their reasoning, specifically using the terms “slope” and “speed” in order to describe their motion to the class. | | |
| Graph K | Start at the origin, move slowly into the positive region with an increasing speed |  |
| Possible teacher responses:  Students should note the change in the QUALITY of the line: curved vs straight. Again, students should be able to verbalize the fact that with a changing slope, there is a corresponding change in speed. These motions are no longer simple linear relationships between position and time. Curved lines indicate that the motion is not uniform; the speed (in the case of linear motion) is changing from one moment to the next. There is no need to use the word acceleration at this point, although students should be made aware of the fact that this type of motion is qualitatively different than everything presented previously. | | |
| Graph L | Student should stand in stupefied silence | Walk forwards, then backwards to the origin |
| Possible teacher responses:  Students will usually notice that this is not a possible graph for a single object. To see why, the teacher can ask about the location of the object at particular moments, eventually coming to a point where the object must exist at two spots at once. Students that try to walk forwards, then back are still possessed of the misconception that the line indicates the path of the object. | | |

POST ACTIVITY DISCUSSION PROMPTS

Much of the discussion should happen while the activity is taking place, although the final slide can be used to quickly summarize the important points for the students.

There is also the opportunity to ask one student to make a graph and another student execute it. Alternatively, a student could move along the axis and another student graphs the motion in real time or after the completion of the motion. In all cases the goal should be a quick and intuitive interpretation of x(t) graphs, completely independent of numerical analysis.

It may be interesting to ask students how they might graph the teachers motion as they walk around the classroom (either 2 independent graphs of x(t) and y(t), a 3-d graph with 2 spatial dimensions along 2 axis and time along the 3rd, etc)

As much as possible, point out that many of the graph analysis tools acquired in math class are entirely appropriate when analyzing these graphs: calculating the rise or the run, finding the slope of a line, finding the x or y intercept, etc. Interpretation of those numbers in a physics context should be the only new skill needed (what does the x-intercept mean? What does the rise indicate?)