Unit 1 – Module 1

Measuring walking speed (Berated activity)

RATIONALE

At the beginning of a physics course, the most important idea to communicate is that we will be modeling physical situations using numbers and mathematical relationships in order to be able to make predictions about the future. Students will need to practice imagining the physical situations described, ascribing numbers to physical quantities and relying on algebra and common sense to make predictions. Nominally, this lab is to develop the student’s ability to measure their own walking speed, but its placement in the course confers on it other responsibilities, as well – the teacher can use this experience to get to know students (the material is not overly difficult), show that the activity objective dictates the actions in the lab, and to work with students individually to assess mathematical capabilities, reactions to challenges, and attention to detail. The data is very easy to gather, which means that there is enough time to allow students to make mistakes early on in the lab, discover their errors as they process the data, and then go back and fix their problems before the end of the class period. Most importantly, because students already know what “faster” and “slower” mean, this activity can be used to demonstrate the way in which the mathematics of the situation mirror reality at a very obvious and intuitive level.

The lab sheet provided should be carefully scrutinized by the teacher and modified to suit the level and number of students participating in the activity. Some teachers may decide that a blank data table needs to be provided for the students, or that there should be more structure for the students to describe their data gathering process, or that the additional questions need to be more complex or subtle. As with all instructional materials, those modifications should be made at the discretion of the teacher based on his or her judgment.

The most effective instruction will probably take place as the teacher circulates amongst the lab groups, asking them to describe what they are doing, why they are doing it and what would it mean if certain things changed. Also, this is an opportunity to give immediate feedback as students create written calculations, allowing the teacher to reiterate or explain some of the conventions used when showing work in a physics class. The post-lab class discussion can also be an effective way to strengthen conceptual relationships and highlight significant ideas present in the activity (the CE and PE items). During this post discussion the class will be able to use actual walking speeds, which can be paired with actual distances or times from their lives, which can help to emphasize the relevance of the material (the teacher may wish to pre-measure the distances to other classrooms in the school, determine the distance to a familiar landmark, know how much time students have in between class bells, etc.)

This activity could take as few as 10 minutes for students who knew what they were doing. For some students 40 minutes will not be enough time to gather good data. The additional questions provided at the end of the lab are simple enough so that they can be completed at home individually, should a group not have time in class. For groups that feel they are finished early, there are many ways to provide additional challenges or tasks (walking exactly 10 m using nothing but a stop watch, measuring exactly 6 seconds using nothing but a meter stick, determining speeds of other types of locomotion (dancing, the worm, walking backwards, heel-toe, grapevine, etc), or performing other tasks such as using a meter stick to accurately determining the length of a long school hallway. These activities are often useful in the post-lab discussion as fodder for whole-class problems.

PRIOR KNOWLEDGE AND SKILLS

* units for distance and conversions (can be done prior to English-SI conversions)
* units for time and conversions
* the definition of a rate
* experience calculating rates and quantities (can be done prior to time calculations)

CE’s AND PE’s

5. Recognize rates as an amount over time in multiple contexts – distance covered/time, water flow/time, money earned/time, and so on.

* speed is a type of rate – one where the quantity involved is distance, or change in position
* a rate is a ratio between quantities, so the magnitudes of the 2 quantities involved may be very different, yet yield the same rate
* a full description of motion requires direction as part of the vector quantities of displacement and velocity
* constant speed is the ratio of equal distances over equal times which results in a linear equation typically written as distance as a function of time, the slope of which is the constant speed (constant velocity requires the additional qualification of in the same direction)
* looking forward to graphing in Unit 1 Module 2, constant speed motion results in a straight line graph where the slope is found by taking the ratio of the distance to the time
* people usually walk with a velocity of about 1 or 2 m/s.

*11. Measure distance accurately in SI units*

* a change in position can be measured with simple tools, like meter sticks or rulers
* how to use a meter stick to make distance measurements in SI units
* how long a meter is, with respect to objects in their everyday experience

*13. Measure time accurately in SI units*

* a change in time can be measured with simple tools like a clock, stopwatch, or metronome
* how to use a stopwatch to make time measurements in SI units

15. Define speed as a particular rate – the rate at which position changes

*16. Measure the speed of an object, using appropriate tools*

*17. Use the definition of average speed to calculate speed, distance covered or elapsed time*

PHYSICS CONVENTIONS

* the accuracy of lab measurements is limited to the devices and techniques used by the experimenters
* objects in this class will be treated as point particles, despite the fact that they are in fact extended objects
* the default reference frame in this class is the surface of the earth

STUDENT GROUPING

Students can work independently, though it is more productive if they work in groups of 2-3. Groups that are too large will have too much down time while other group members are gathering data.

MATERIALS

FOR EACH GROUP

-space to walk freely in a straight line for between 3-10 meters

-roll of masking tape

-a meter stick

-a stopwatch

FOR EACH STUDENT

-copy of handout

-pen/pencil

TIMELINE (about 40 minutes)

5-10 minutes – lecture to relate rate to speed, outline objectives for the activity

3-5 minutes – get into groups/gather materials/find appropriate locations to gather data

25-30 minutes – data gathering and processing

-lay out measured distance (optional)

-perform walking trials

-gather time (or distance) data

-draw diagram of set-up

-perform calculations

-write responses to prompts

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| **Stage of activity** | **What the students should do** | **Student mistakes** |
| Activity introduction (teacher lecture) | Recognize the task assigned and imagine ways to accomplish the task | Expect handout with explicit instructions |
| Possible teacher responses:  Encourage all methods of attacking the problem  Reiterate the rationale for the activity as well as the CE’s and PE’s | | |
| Gathering materials | Based on the need for time and distance data, gather stopwatch and meter stick | Forget the need for time data and just grab meter sticks |
| Possible teacher responses:  Wait | | |
| Measuring out distances (one possibility for solving the problem) | Measure out a reasonably long distance (3-8 m) to minimize the significance of the inherent absolute errors in timing | Measure out 1 m |
| Possible teacher responses:  Ask why they chose 1 m instead of a smaller distance, like 1 cm? This prompt can force them to think about the potential timing errors | | |
| Measuring the time (for a fixed distance) | Have a consistent part of the body as the location of the moving object (front of the foot, middle of torso, etc) | Start with heel on start line and finish with toe crossing the end line |
| Possible teacher responses:  Ask what information the stopwatch is giving them. While many recognize that the stopwatch gives time information, they have much more difficulty identifying the time TO DO WHAT? Eventually, they can see that it is the time for the object to traverse the given distance, so now you can ask the question: where is the object? Now they can see that if the extended object is to be properly reduced to a point, then they must have consistency in their identification of the object | | |
| Measuring the time (for a fixed distance) | Take multiple trials | Take a single data point |
| Possible teacher responses:  Ask the student to run the experiment again. Ask why the results are not exactly the same as the first trial. Which one is correct? If the student has to give a single number to describe their walking speed, which one would they choose? Why would only one of those numbers be right and the other wrong? How can they come up with the best single number that gives the walking rate? | | |

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| Measuring the time (for a fixed distance) | Students should be aware of perspective when gauging when the object crosses the finish/start line. | Stationary timer will have a skewed perspective of the object crossing one of the lines |
| Possible teacher responses:  Can be addressed with student groups who seem comfortable with the rudiments of the lab and ignored for students who struggle with the basics. Capable groups should determine their own solution to the problem (walker carries stopwatch/ timer moves with walker/walker signals crossing line, etc) and re-take data | | |
| Measuring the distance (for a fixed time) | Some student groups may elect to walk for a fixed amount of time and measure the distance traveled | Many similar errors as fixed distance method  -time too short  -vague object location |
| Possible teacher responses:  This is a perfectly viable method of doing the lab, the only drawback is that it takes more time to measure out the distances for each trial and these groups may have trouble gathering all of their data and processing it during the class period | | |
| In all of the activities above students are trying to find a reliable way to measure a distance covered in time. It is this constant ratio that is the key. If they measure the time it takes to walk 3 meters, they should find that it takes double that time to walk 6 meters. If they find that they walk 3.5 meters in 2 seconds, then they should walk 7 meters in 4 seconds. And in all of the data processing below, they should be finding that the speed is a constant. For example, if a group found the speed in two different ways, both should result in the same value for the speed. | | |
| Data processing | Students average time data to compute speed or average speeds and average final results | Don’t know how to process multiple trials |
| Possible teacher responses:  Have students do the calculations both ways (finding average before and after speed calculation) to see that with linear relationships either method gives the same result | | |
| Data processing | Students notice that calculating speed takes two different measurements that have two different units, one of which is a distance unit and the other is a time unit | Students mechanically divide two numbers |
| Possible teacher responses:  The calculations for this activity require one step, but as they get more complicated the take-home message or big idea of the activity should not be lost or neglected in favor of finding “the answer.” | | |

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| Data processing | Students show units when doing calculations | Students show just the numbers |
| Possible teacher responses:  Point out that the meaning is obvious in this context, but when problems become more complex (how far could you walk in 4 minutes? In 4 hours? Is the distance the same?) the units associated with the numbers will be important | | |
| Data processing | Students calculate the speed by taking distance/time | Students calculate the speed by taking time/distance |
| Possible teacher responses:  Ask what should happen to the speed if you walk the distance in a shorter/longer time. Is that reality reflected in the way they have manipulated the data? Point out that what they calculated is a perfectly good way to talk about how fast they were moving, but it is not called the speed. | | |
| Data processing | Students reduce the fraction to determine speed in meters/ONE second | Students leave the speed with non unitary time |
| Possible teacher responses:  Ask how far they would go in 10 seconds? 87 seconds? Note that if rate as given as x meters/sec, then calculations become simpler, hence the convention of putting single units of time in the denominator | | |
| Data processing | Students may convert meters to miles and seconds to hours and then divide the two to find mph | If done properly, the SI data gathered by the students will yield very small numbers of miles and hours. Many students lose their number intuition at this point and get lost, sometimes assuming that they have gotten wrong answers from their conversions because the numbers are so small |
| Possible teacher responses:  Ask student which is bigger, a mile or the distance they just walked in the classroom. Is the distance walked about half a mile (which is 0.5 miles), less? (a tenth of a mile (0.1 miles) etc | | |
| Connecting numbers to experience | Students know that the speed of walking is about 1-2 m/s and approximately 3 mph. | Students mechanically calculate the speed of walking |
| Possible teacher responses:  Two important skills in physics are estimating and connecting numbers (values) to reality. Fermi problems epitomize the “guesstimation” that physics strives to teach students. | | |

POST ACTIVITY DISCUSSION PROMPTS

What numbers did people get for their walking velocity?

-importance of units (is 2 m/s faster or slower than 2 mph? Are they the same speed?)

-importance of having some reference numbers when making estimations and judging the validity of calculations (is it reasonable to have a car on the highway going 3 m/s?)

-estimate (in m/s) some values for a person running, a car driving along, a thrown baseball, etc

Did all groups use the same method to determine walking speed?

-important thing was to find a known distance in a known time. Some groups can chose to fix the distance, or to fix the time. (can actually do it a 3rd way, where both are arbitrary)

-the “best way” to find an answer depends on the materials available and the care taken in gathering data

Did all of your trials come out with the same number (of seconds or meters)? Why was there some irregularity in the data? How does that impact the answer to the question: “what is your walking speed?”

-single data points can be misleading

-averaging data can summarize many trials to a single number, but with some loss of information

-averaging numbers can reduce random errors, though not systematic errors

If person A walks 8 m in 8 s, and person B walks 4 m, can you tell who has the biggest walking speed?

-speed is the ratio of distance AND time, both bits of information are needed

If person B walks 4 m in 4 s, what is their speed compared to person A?

-speed is a ratio, and so the magnitudes of the quantities involved is not important.

Can something have a speed of 10 m/s if it only goes a distance of 3 m?

-speed is a ratio, not the distance and not the time

Is it OK to talk about speed in terms of 6.43 m/5.3 s?

-standard method of representing speed as distance/unit time

-units for speed (and later, velocity), will always take the form of some distance/some time. Hence, despite being a mixture of units, it may help to think about the

“units for speed” as being a single unit

Use the personal walking data to calculate some relevant facts:

-how far can you walk during the time in between class bells during the passing period?

-if the distance from one classroom to another is \_\_\_\_\_\_, how long would it take for you to walk that distance?

-if it takes \_\_\_\_\_\_\_\_ to walk home, how far away do you live?

-How long would it take to walk to New York

Unit 1 – Module 1

A constant speed activity which leads to graphing motion data

RATIONALE

The walking activity provides a good introduction to motion, allowing students to connect a well known concrete physical activity to more abstract concepts like a constant rate of motion. The next step is to go from qualitative to quantitative including equations and graphing. This requires better data.

PRIOR KNOWLEDGE AND SKILLS

* experience collecting data in tables
* experience graphing data
* students often do not know how to read instruments to the right level of accuracy

CE’s AND PE’s

*11. Measure distance accurately in SI units*

*13. Measure time accurately in SI units*

15. Define speed as a particular rate – the rate at which position changes

* 1. For an unambiguous description of motion there needs to be
     1. An object for reference
     2. A coordinate axes that are tied to the object of reference above
     3. A reference clock

*16. Measure the speed of an object, using appropriate tools*

*17. Use the definition of average speed to calculate speed, distance covered or elapsed time*

PHYSICS CONVENTIONS

* when graphing, the x-axis is typically time while the y-axis is typically distance, velocity or acceleration