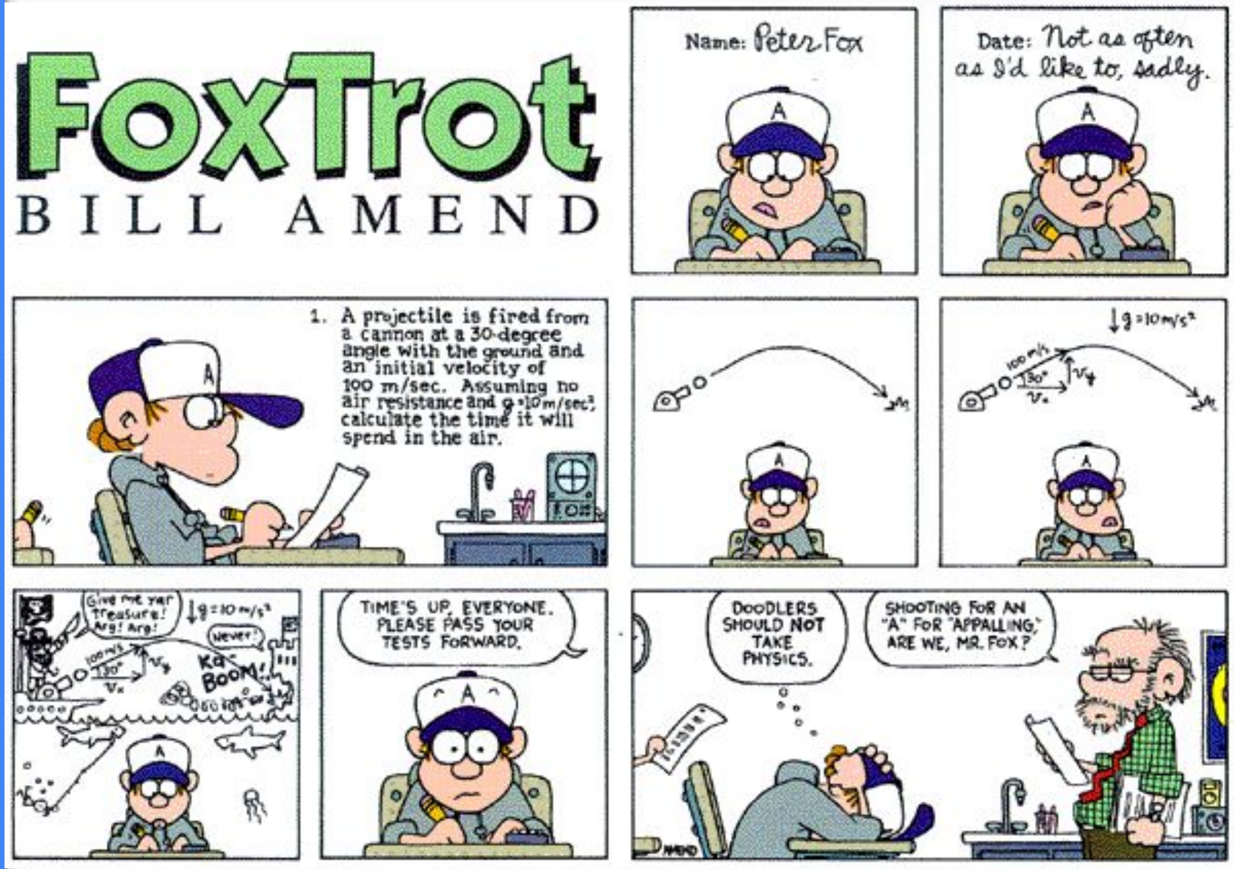
Physics Education Laboratory Lecture 05 - p2

Kinematics Concepts and Pedagogical approach with Multiple Representations

Francesco Longo • 09/10/2023

Real world


FoxTrot
BILL AMEND
Name: Peter Fox
Date: Not as often as I'd like to, sadly.
1. A projectile is fired from a cannon at a 30-degree angle with the ground and an initial velocity of 100 m/sec. Assuming no air resistance and g = 10 m/sec², calculate the time it will spend in the air.
Give me yer treasure! Arg! Arg!
Never!
Ka-BOOM!
TIME'S UP, EVERYONE. PLEASE PASS YOUR TESTS FORWARD.
DOODLERS SHOULD NOT TAKE PHYSICS.
SHOOTING FOR AN "A" FOR "APPALLING," ARE WE, MR. FOX?

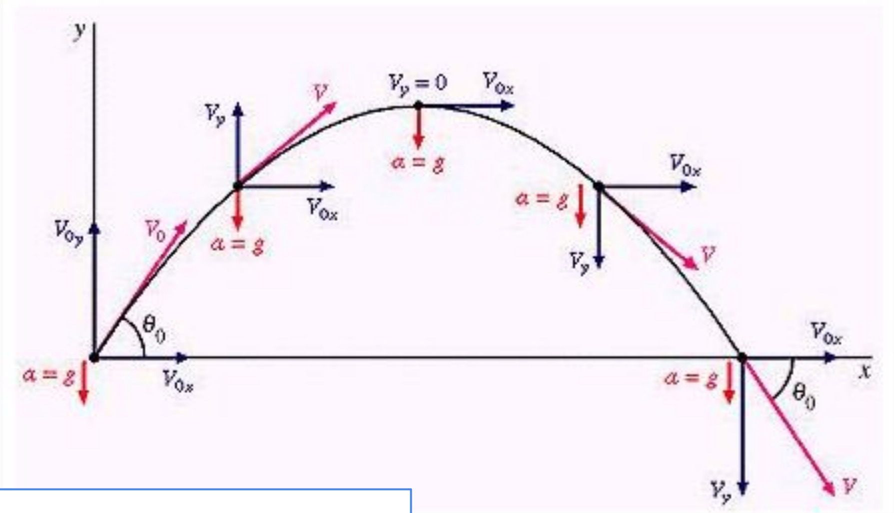
Key-concepts in kinematics

Defining quantities/variables for describing motion (position, displacement, speed, velocity, acceleration)

Frame of reference and observers

From one dimensional to bi-dimensional motion (from scalars to vectors)

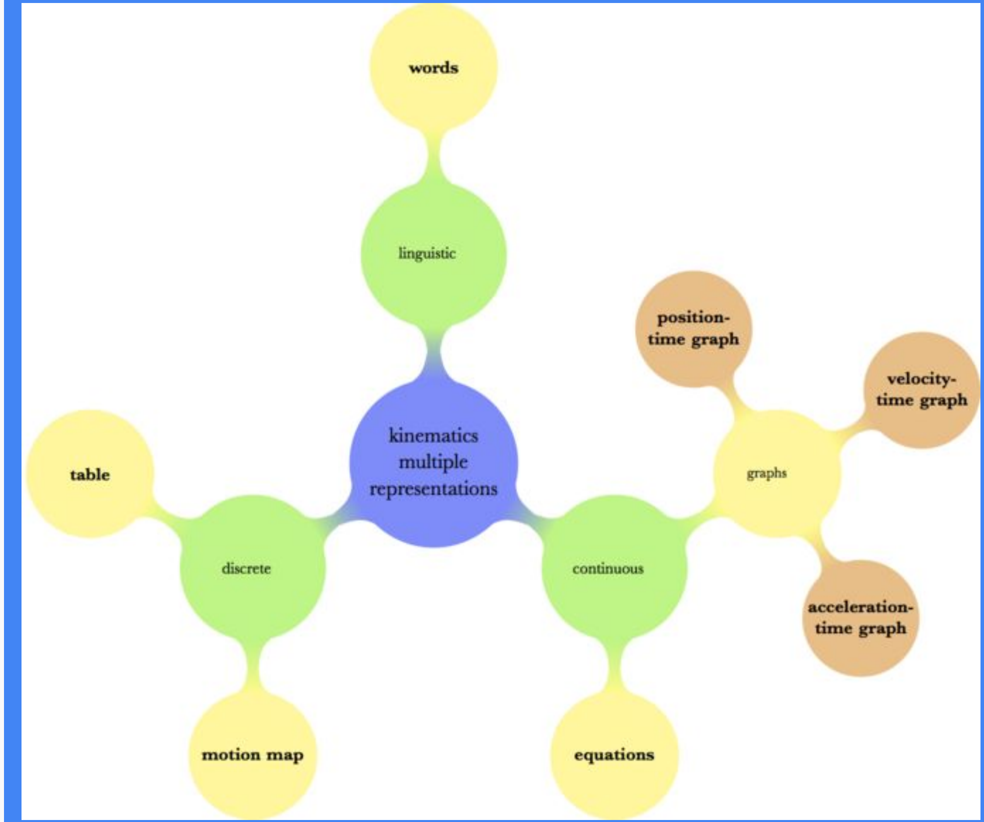
Relative motion



Knowledge of curricula

Key-concepts in Kinematics with Multiple Representations

Orientation toward science teaching



https://fockphysics.wordpress.com/2013/06/15/sbg-and-multiple-representations-in-kinematics/

Students' difficulties in kinematics graphs

Knowledge of students' prior understanding

(Beichner, 1994)

Graph as Picture Errors
The graph is considered to be like a photograph of the situation. It is not seen to be an abstract mathematical representation, but rather a concrete duplication of the motion event.

Slope/Height Confusion
Students often read values off the axes and directly assign them to the slope.

Variable Confusion
Students do not distinguish between distance, velocity, and acceleration. They often believe that graphs of these variables should be identical and appear to readily switch axis labels from one variable to another without recognizing that the graphed line should also change.

Nonorigin Slope Errors
Students successfully find the slope of lines which pass through the origin. However, they have difficulty determining the slope of a line (or the appropriate tangent line) if it does not go through zero.

Area Ignorance
Students do not recognize the meaning of areas under kinematics graph curves.

Area/Slope/Height Confusion
Students often perform slope calculations or inappropriately use axis values when area calculations are required.

Quantitative/Qualitative problem solving in symbol representation

formats, are crucial. It is well known that the application of quantitative strategy (manipulation of equations for attempting problems) does not imply comprehension of concepts presented in the tasks as well as the underlying physics principles of the equations used. According to the Johnson-Laird cognitive framework of sense making [45], it is argued that comprehension occurs with the construction of a mental model which is a key element in the learning process [46,47]. However, although the application of external representations promotes the construction of a mental model, the strategies used by the students when attempting tasks with different representational formats play a crucial role. The study by Greca and Moreira [48] characterized students with a mental model as focusing on comprehension and identifying physics ideas, using a qualitative appr… ing visual repr… with the equati… problem solving… taught and pro… various ways i… representations… on the use of q… central role of v… ing as well as f… be highlighted. … constructing m… promoted, thu… Moreover, the … with the differ… decoding, inter… particular repr… across different… These are some… et al. [17] whic…

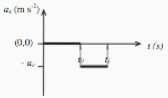


FIG. 1. Kinematic task with graphical format requesting qualitative solution.

immediately apply the brakes and your car starts slowing down at 0.8 m s^{-2}. Determine whether a collision will take place.

Specific strategies to assess students' understandings

ACKNOWLEDGMENTS

This work is supported in part by the U.S. National Science Foundation under Grant No. 0816207.

APPENDIX A

Question 1: Kinematics—Qualitative—Symbolic

The equation of motion for an object moving along a straight horizontal path is given by

$$x(t) = 30 + 5t + 2t^2$$

Write down, in words, everything you can say about the motion of the object.

Question 2: Kinematics—Quantitative—Linguistic

You are driving at a speed of 60 m s^{-1} when suddenly you see a van 60 m directly ahead of you also travelling in the same direction at a constant speed of 40 m s^{-1}. You

Question 6: Work—Qualitative—Symbolic

Write down everything you can say from the force equation $\vec{F}(x) = (-4 + x^2)\,\hat{i}$ N applied to move the box from an initial position of 0 m to final position of 4 m.

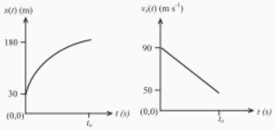


FIG. 2. Kinematic task with graphical format requesting quantitative solutions.

The equation of motion for an object moving along a straight horizontal path is found to be

$$v_x(t) = 3 + 2t$$

If the object was in motion for 5 s, what is the distance travelled and acceleration during this time?

The equation of motion for an object moving along a straight horizontal path is given by

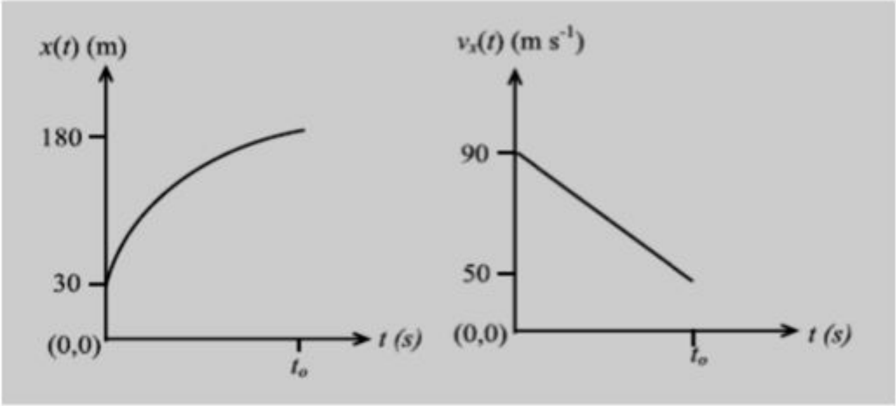
$$x(t) = 30 + 5t + 2t^2$$

Write down, in words, everything you can say about the motion of the object.

(Ibrahim & Rebello, 2012) (Saputra et al. 2019)

Quantitative/Qualitative problem solving in Graphic representation

(Ibrahim & Rebello, 2012) (Saputra et al. 2019)

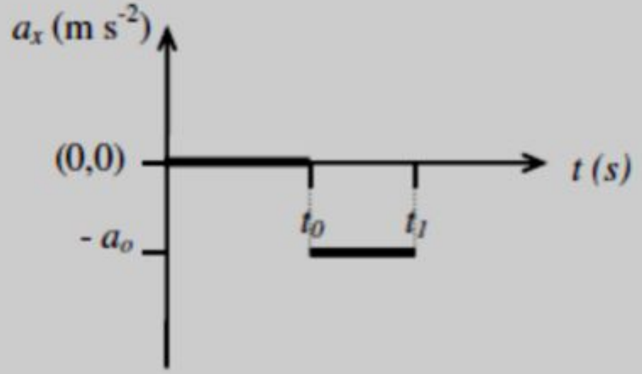


The motion of a truck along a straight horizontal path is shown by the graphs below. Determine the time taken and acceleration of the truck to complete the whole journey

Specific strategies to assess students' understandings

The acceleration-time graph for an object moving along a straight horizontal path is shown in Fig. 4.

Write down, in words, everything you can say about the motion of the object



Questionnaire on Kinematics - Let’s try it

https://forms.gle/eX4cFVu9QkHzEyzA7

Multiple Representations definition

MR refer to the capacity of scientific discourse to represent the same concepts or processes in different modes (e.g., verbal, visual, mathematical, graphical) while multi-modal representation refers to the integration of different modes to represent scientific processes, findings, and scientific explanations

Tytler et al. (2007) p.314

DEFINING REPRESENTATIONS:

External representations: which are in a form that can be seen by others, such as pictures, text narrations, graphs, symbols, etc.

External representations refer to “the knowledge and structure in the environment, as physical symbols, objects, or dimensions”

Internal representations or **mental models**, which act out as structural analogies of situations or processes.

Ainsworth (1999,2008)

Internal representations refer to “the knowledge and structure in memory, as propositions, productions, schemas, neural networks, or other forms” Zhang (1997)

Building deep learning

Information in external representations can be processed by perceptual operation and refers to information that is directly perceived.

Information in internal representations refers to information retrieved directly from working memory that involves cognitive operation.

Through memorization, an internal representation can be transformed to an external representation.

Multiple Representations

In what ways does the use of MR in instruction support student learning?

MR might serve as a powerful learning strategy in physics education and has a positive impact on undergraduate students' conceptual understanding of physics concepts.

Different representations might be used for different purposes and also depending on students' prior experience with the use of a specific kind of representation.

Multiple Representations

What kinds of representations do students use?

Students use different kinds of representations and the combination or a series of kinds of representations has the potential to support student problem solving and consequently their development of conceptual understandings.

Multiple Representations

What difficulties do students face in using MR?

Even though MR provide an empowering learning tool or learning strategy, students face different difficulties in using MR during the learning process, especially in switching between kinds of representations.

Multiple Representations

What is the relation between students' use of MR and students' problem-solving skills?

The kind of representation used impacts students' problem-solving success.

Multiple Representations

What is the added value of technology integration in teaching with MR?

The potential value of computer-based MR in supporting students’ physics learning such as supporting students’ conceptual understandings as well as their representational competence.

SUMMARIZING:
how multiple representations (MR) can be used in undergraduate physics education and in physics education research

- MR might serve as a powerful learning strategy in physics education and has a positive impact on undergraduate students' understanding of physics concepts.
- There is no evidence in the literature that one kind representation is better than another in supporting students develop their understandings of physics concepts.
- Students use different kinds of representations and the combination of kinds of representations has the potential to support student problem solving and consequently their development of conceptual understanding.
- Students face different difficulties in using MR during the learning process, especially in switching between kinds of representations.
- Computer-based representations can support students' physics learning, as for example, conceptual understanding and representational competence.

State of PER results:

Research shows that the use of MR might enhance student learning

Research also shows that students have difficulties in relating and integrating the representations and translating information between them

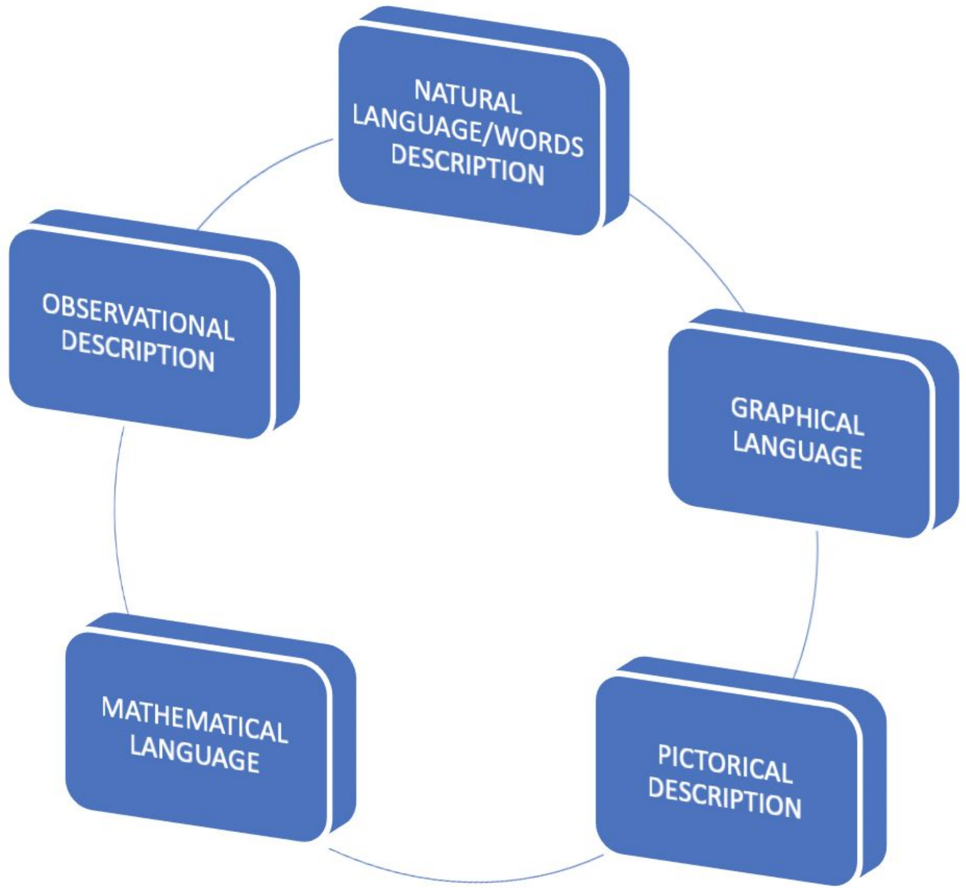
Learning outcomes: MR might have **three** distinct roles in learning.

- MR serve a **complementary role** given that using texts and pictures together will complement each other
  - Students can choose what the best way is for them to learn
  - Students can also combine representations that can make learning easier
  - Students can use texts, pictures, graphs, tables and other representations. This means that one problem can be solved with the use of several representations.
- MR supports the development of a deeper conceptual understanding.
  - This role relates to the ways in which MR might enhance abstraction, extension, and relation.
  - The students who have a deep understanding of certain concepts can transform one kind of representation into another kind of representation
- MR employs common representations and by using inherent properties of one (common) representation to develop the interpretation of the second representation (uncommon)

“MR have a great potential in supporting student learning of physics concepts because students learn easier when problems include MR, hence, the use of MR can maximize the results of students’ learning processes. “

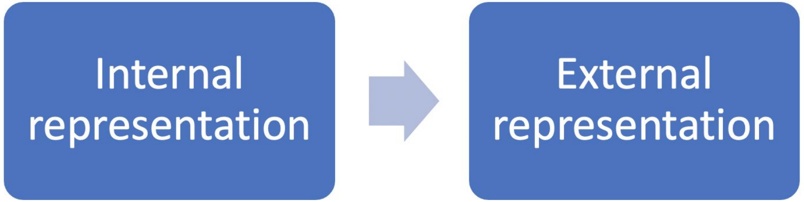
Opfermann M., Schmeck A., Fischer H.E. (2017) Multiple Representations in Physics and Science Education – Why Should We Use Them?. In: Treagust D., Duit R., Fischer H. (eds) **Multiple Representations in Physics Education. Models and Modeling in Science Education**, vol 10. Springer, Cham. https://doi.org/10.1007/978-3-319-58914-5_1

Kinematics with Multiple Representations DESCRIPTIONS OR DISCIPLINE’S LANGUAGES?

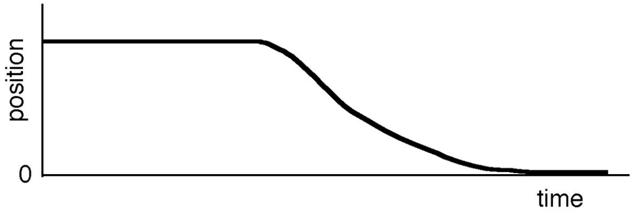

NATURAL LANGUAGE/WORDS DESCRIPTION
GRAPHICAL LANGUAGE
PICTORICAL DESCRIPTION
MATHEMATICAL LANGUAGE
OBSERVATIONAL DESCRIPTION

Interpreting representation and translating

FROM GRAPHICAL TO WORDS



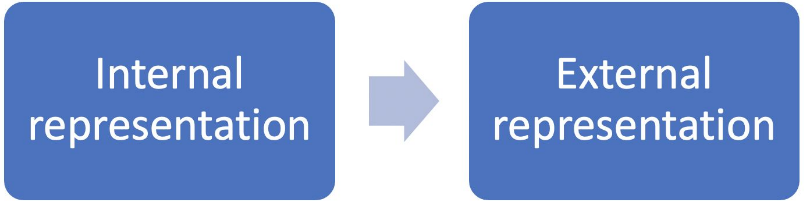
6. Here is a graph of an object's motion. Which sentence is a correct interpretation?



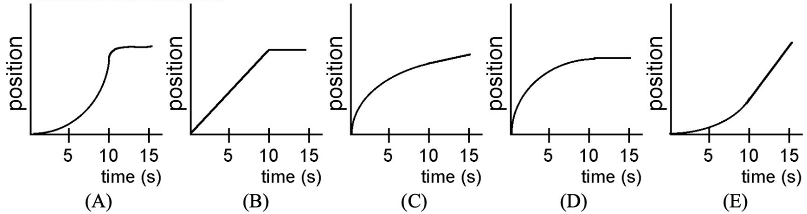
A) The object rolls along a flat surface. Then it rolls forward down a hill, and then finally stops.
B) The object doesn't move at first. Then it rolls forward down a hill and finally stops.
C) The object is moving at a constant velocity. Then it slows down and stops.
D) The object doesn't move at first. Then it moves backwards and then finally stops.
E) The object moves along a flat area, moves backwards down a hill, and then it keeps moving.

Interpreting representation and translating

FROM WORDS TO GRAPHICAL

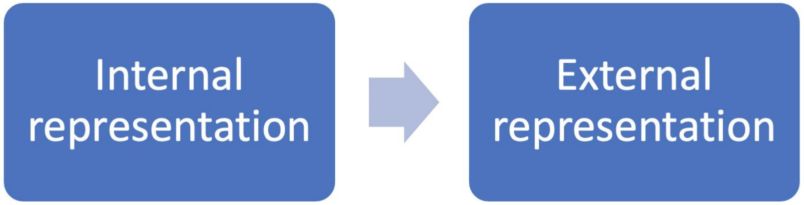


7. An object starts from rest and undergoes a positive, constant acceleration for ten seconds. It then continues on with constant positive velocity. Which of the following graphs correctly describes this situation?



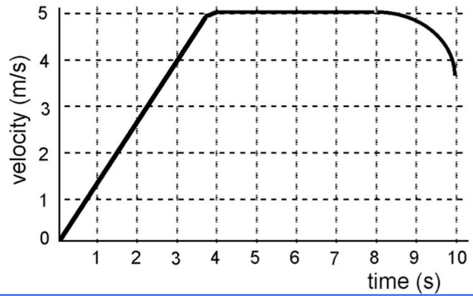
Interpreting representation and translating

FROM WORDS THROUGH GRAPHICAL TO MATHEMATICAL



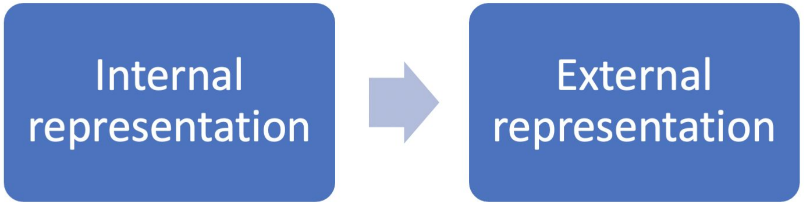
3. An elevator moves from the basement to the tenth floor of a building. The mass of the elevator is 1000 kg and it moves as shown in the velocity-time graph below. How far does it move during the first three seconds of motion?

A) 0.75 m
B) 1.33 m
C) 4.0 m
D) 6.0 m
E) 12.0 m



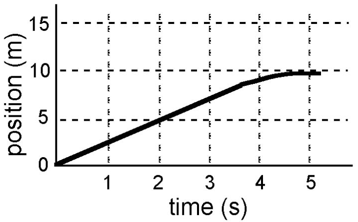
Collecting data and elaborating

FROM GRAPHICAL TO MATHEMATICAL



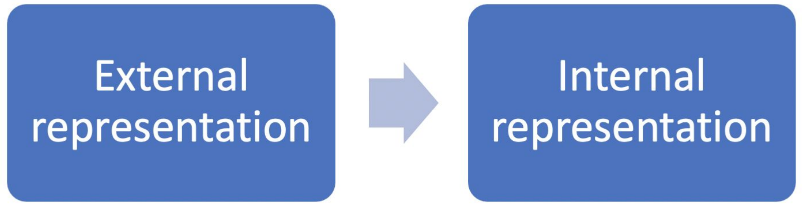
4. The velocity at the 2 second point is:

   A) 0.4 m/s
   B) 2.0 m/s
   C) 2.5 m/s
   D) 5.0 m/s
   E) 10.0 m/s

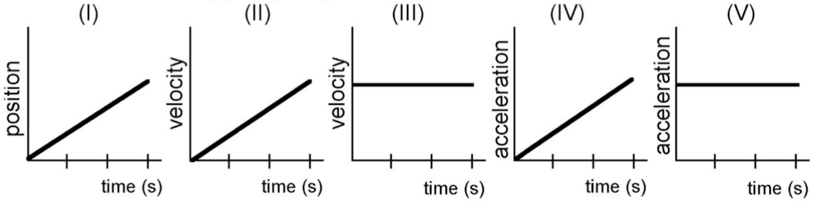


Interpreting representation and modelling concept

FROM GRAPHICAL TO CONCEPT MODEL



9. Consider the following graphs, noting the different axes:

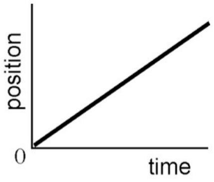


Which of these represent(s) motion at constant velocity?

A) I, II, and IV
B) I and III
C) II and V
D) IV only
E) V only

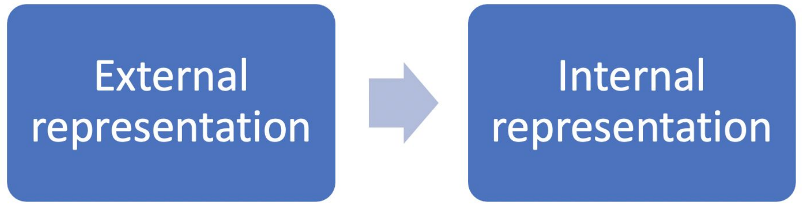
2. To the right is a graph of an object's motion.
Which is the best interpretation?

A) The object is moving with a constant, non-zero acceleration.
B) The object does not move.
C) The object is moving with a uniformly increasing velocity.
D) The object is moving at a constant velocity.
E) The object is moving with a uniformly increasing acceleration.

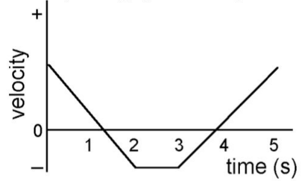


Interpreting representation and modelling concept

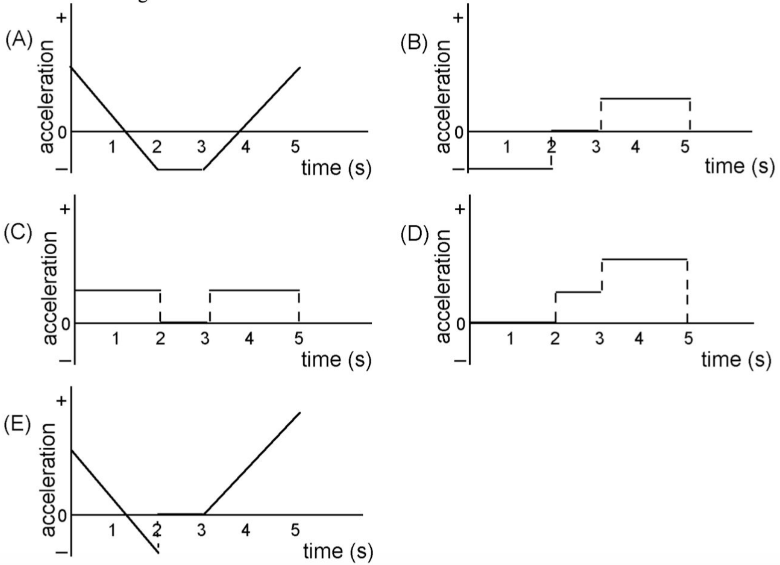
FROM GRAPHICAL TO CONCEPT MODEL



11. The following represents a velocity-time graph for an object during a 5 s interval.

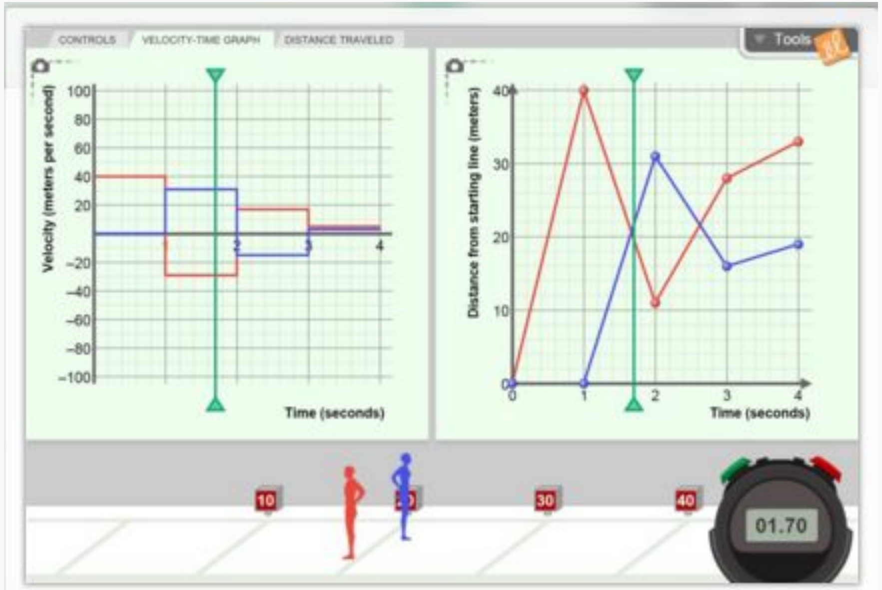


Which one of the following graphs of acceleration vs time would best represent the object's motion during the same time interval



Distance -Time, Velocity-Time Graphs Metric

Create a graph of a runner's position versus time and watch the runner run a 40-meter dash based on the graph you made. Notice the connection between the slope of the line and the velocity of the runner. Add a second runner (a second graph) and connect real-world meaning to the intersection of two graphs. Also experiment with a graph of velocity versus time for the runners, and also distance traveled versus time.



https://www.explorelearning.com/index.cfm?method=cResource.dspDetail&ResourceID=626

Students' Exploration Sheet

Analyze the sheet

Observe the use of Multiple Representations

Add one or more exercises to improve the Multiple Representations usage of this sheet

What's missing?

Student Exploration: Distance-Time and Velocity-Time Graphs

[NOTE TO TEACHERS AND STUDENTS: This lesson was designed as a follow-up to the Distance-Time Graphs Gizmo. We recommend you complete that activity before this one.]

Vocabulary: displacement, distance traveled, slope, speed, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
Dora runs one lap around the track, finishing where she started. Clark runs a 100-meter dash along the straight side of the track.

1. Which runner traveled a greater distance? _______________

2. Which runner had a greater change in position, start to finish?

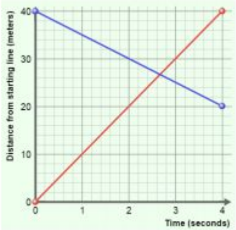
____

Gizmo Warm-up
The *Distance-Time Graphs* Gizmo shows a dynamic graph of the position of a runner over time. The *Distance-Time and Velocity-Time Graphs* Gizmo includes that same graph and adds two new ones: a velocity vs. time graph and a distance traveled vs. time graph.

The graph shown below (and in the Gizmo) shows a runner's position (or distance from the starting line) over time. This is most commonly called a *position-time graph*.

Check that the **Number of Points** is 2. Turn on **Show graph** and **Show animation** for both **Runner 1** and **Runner 2**.

1. Drag the points to create the graph shown to the right.
   - **Runner 1**'s line (the red one) should have endpoints at (0, 0) and (4, 40).
   - **Runner 2**'s line (the blue one) should have endpoints at (0, 40) and (4, 20).



https://docs.google.com/document/d/1pk9zP-_VjpS3WDc2iDA2qNbapCN4Z8Bhc7pYrVoEluM/edit

Proposals

1. Two students have to catch a bus. The first one wakes up earlier. The second one has to catch the same bus at 40 m at the same time. What is his/her velocity?
2. Try the “telefono senza fili” alternating representations …
3. Test the velocity for “giving a 5” at a different position