The focus of this instructional segment is to introduce students to the concepts of motion including displacement, velocity, and acceleration. This will also include a discussion of vectors and scalars and the independence of the x- and y-components of a projectile's motion. Students will also gain experience with using and creating motion graphs.

Student Science Performance

Grade or Course: 9-12 Physics	**Title**
Topic: Kinematics in one- and two-dimensional motion	**Dropped vs. Launched**

Performance Expectation for GSE:

SP1. Obtain, evaluate, and communicate information about the relationship between distance, displacement, speed, velocity, and acceleration as functions of time.

a. Plan and carry out an investigation of one-dimensional motion to calculate average and instantaneous speed and velocity.

- Analyze one-dimensional problems involving changes of direction, using algebraic signs to represent vector direction.
- Apply one-dimensional kinematic equations to situations with no acceleration, and positive, or negative constant acceleration.

b. Analyze and interpret data using created or obtained motion graphs to illustrate the relationships among position, velocity, and acceleration, as functions of time.

c. Ask questions to compare and contrast scalar and vector quantities.

d. Analyze and interpret data of two-dimensional motion with constant acceleration.

- Resolve position, velocity, or acceleration vectors into components (x and y, horizontal and vertical).
- Add vectors graphically and mathematically by adding components.
- Interpret problems to show that objects moving in two dimensions have independent motions along each coordinate axis.
- Design an experiment to investigate the projectile motion of an object by collecting and analyzing data using kinematic equations.
- Predict and describe how changes to initial conditions affect the resulting motion.
- Calculate range and time in the air for a horizontally launched projectile.

Performance Expectations for Instruction:

Students will

- design and implement an investigation to determine the exact location that two constant velocity carts will cross paths.
- manipulate and apply kinematic equations to one-dimensional and two-dimensional motion.
- develop and apply motion graphs for constant and accelerated motion.
- design an experiment to investigate phenomena.

Additional notes on student supports

Materials

- Constant velocity cars
- Marbles or ball bearings with track or channel
- Meter sticks, stopwatches, graph paper

Engaging Learners	**Anchor Phenomenon: Will a dropped marble and launched (horizontally) marble hit the ground at the same time?** **Lesson Phenomenon: Two cars will collide at a precise and predictable point.**
	Obtaining: How are the use of kinematic equations depicted in motion graphs to predict an object's position?

<table>
<tr><td></td><td>In this section of the lesson, students will obtain information about the constant velocity car that their group is given. At this point, students understand how to measure displacement and time and calculate velocity using kinematic equations.</td></tr>
<tr><td></td><td>Evaluating
Students develop position-time graphs for their constant velocity cars. Each group should have multiple trials and/or measurements to determine their car's velocity.</td></tr>
<tr><td></td><td>Communicating
To communicate information, students will present their data to another group they will pair up with. By showing graphs, measurements, and calculations, students are communicating that an object's displacement, velocity, and time are predictable.

<u>See Student Handout: Car Collision Student Sheet</u>

<u>Teacher Note:</u> As students begin making measurements and analyzing their car's motion, they will be exposed to the kinematic equations and the variables contained. Guide student groups to consider scale, units, and proper technique.

After determining the velocity of their car and completing handout, students will work with another group (with a different velocity) and begin designing an experiment to make them cross at a certain point (time or distance). For example, you might tell students the exact point the cars will be starting (going towards each other) and they have to predict the point of intersection; or you can tell students to make their cars intersect at a certain time, i.e. after 4.5 seconds—they must determine the correct starting position.

This is not trial and error; students will develop motion graphs as a model to predict the crossing point. In order to have different cars with different velocities, you can take a battery out and replace with a conductor to reduce voltage; a combination of dead and new batteries will also achieve varying velocities.

Consider a class discussion about the application of using kinematic equations (models); what is a real-world application of these principles?</td></tr>
<tr><td>Exploring</td><td>Obtaining: In this phase, students are working in groups in predicting car intersection points. The experimental data is evidence to support the lesson phenomenon. As students analyze graphs and data of the other group's car, the concept of direction and vector quantities should arise as</td></tr>
</table>

	they realize that separate motion graphs may look similar, but the cars will be traveling different directions when they will intersect.
	Evaluating: Given another point of intersection, student groups are challenged to use their same model as before and predict the new intersection point.
	Communicating: Students will communicate findings of their experiment in two manners: 1. Before student groups present findings on a whiteboard presentation, have students silently and individually write about results. See Car Collisions: Guiding Questions 2. Student groups summarize findings and communicate with a white board presentation. *Teacher Note: For graphing purposes, students can also use graphing calculators or an online graphing calculator, such as Desmos.com to produce graphs.* *The constant velocity cars make use of only one-dimensional motion; however, students will come to realize that they will have to define an axis system as well as a positive/negative direction in order to predict the intersection point. Again, this is not a trial and error exercise; students should not get the opportunity to test the two cars and get an intersection point without predicting it first.* *Class discussion of predictions and any discrepancies is recommended after this part of the activity.*
	Formative Assessment of Student Learning
	Lesson Phenomenon: Will a dropped marble and launched (horizontally) marble hit the ground at the same time?
Explaining Finalizing Model	*Obtaining:* Students will now complete an investigation using accelerated motion. The main task is for student groups to design an experiment to test the dropped vs. fired bullet phenomenon using marbles or bearings, lab tables, and tracks.
	Evaluating: Student models should include multiple representations of data from investigation, such as motion graphs. See Dropped vs. Launched Investigation Student Sheet
	Communicating: Students write and explain their predictions about the dropped vs. fired bullet based on their evidence gathered in this investigation. Allowing students to complete this individually at first will allow more identification of misconceptions or gaps.

	Class discussion: How can the student-developed models be applied to the anchor phenomenon? *<u>Teacher Note:</u> In this part of the lesson, students will gain experience with accelerated motion; they will design an investigation to learn more about the anchor phenomenon. With marbles and tracks, students will compare dropped and horizontally-launched projectiles. Guide students to consider what variables are best measured or calculated to reduce error. Through the investigation, students should understand that horizontal and vertical motions for the projectile are independent of each other.* *It is important that students gain experience with accelerated motion as well as projectile (horizontally-launched) motion in this investigation.*
Elaborating Applying Model to Solve a Problems	*Obtaining:* Students use Curve Stacks to apply their kinematic models to other scenarios. See Curve Stacks Student Sheet *Evaluating, Communicating:* Students apply model to analyze a scenario of an airplane delivering a package. See Airplane Delivery Student Sheet Additional Applications: To extend to other instructional units, students could apply models developed here with kinematics and apply to car crash safety, or something similar to the traditional "Shoot the Monkey" demo/problem.
Evaluation	***Assessment of Student Learning***
	Communicating: At the conclusion of the investigations and activities, students will write about the anchor phenomenon and explain the result using the core ideas in SP1.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Asking questions • Developing and using models • Planning and carrying out investigations • Analyzing and interpreting data • Using mathematics and computational thinking • Obtaining, evaluating, and communicating information
Crosscutting Concepts	• Patterns • Cause and effect • Systems and system models • Energy and matter
Disciplinary Core Ideas	From A Framework for K-12 Science Education: PS2: Motion and Stability This builds upon S8P3 from physical science

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. Provide calculators as needed. 2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student grouping.
2. The teacher should consider using guiding questions to help students recognize the important parts of data that they need to gather when crashing their car.
3. The teacher should consider providing students with graph paper to graph their data.
4. Then the teacher should consider providing students with an ideal graph and have them explain why their graph matches or does not match the ideal graph.
5. The teacher should ensure that students have access to any equations that they may need to complete their assignment.
6. The teacher may need to explicitly teach students to use equations and then provide practice that reinforces correct usage of the equations.
7. The teacher should consider multiple formats for students to share their work. These formats could include using technology, gallery walks or presentations.

8. The teacher may need to provide some students with more information to assist them in pairing up with another group and determining where the cars intersect.
9. The teacher should consider providing students with an organizer for students to illustrate what they see as they work with cars.
10. The teacher should have clear and consistent guidelines for student discussion. These guidelines should assist students in feeling more comfortable and be more likely to participate.

Exploring:

1. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student grouping.
2. The teacher should consider assisting students in analyzing data by showing them how to analyze data and providing practice with using data.
3. The teacher should consider using guiding questions to assist students in moving through the assignment.
4. Students may need additional time to complete their assignment.
5. The teacher should consider a formative assessment to review, re-teach or enrich.
6. The teacher should consider providing multiple formats for students to share their knowledge. These formats could include writing, drawing, diagraming or verbally explaining.
7. The teacher should consider providing students with online graphing tools that they may use to assist with their assignment.
8. Some struggling students may need to work backward from point of impact and use the trial and error method to see where the cars started. The teacher can ask students to explain how they arrived at their answer and then ask the students to provide data to back up their conclusions.
9. The teacher should have clear and consistent guidelines for class discussion. These guidelines should assist students in feeling form comfortable and be more likely to participate in the discussion.

Explaining:

1. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student grouping.
2. The teacher should consider providing multiple formats for students to share their knowledge. These formats could include writing, drawing, diagraming or verbally explaining.
3. Students may need additional time to complete their assignments.
4. The teacher should have clear and consistent guidelines for class discussion. These guidelines should assist students in feeling form comfortable and be more likely to participate in the discussion.
5. The teacher should provide opportunities for practice in using formulas and determining direction as needed.
6. The teacher should consider a formative assessment. Then the teacher can determine which students need reviewing, re-teaching or enriching.

Elaborating:

1. The teacher will need to explicitly show students how to use the curve stacks. The teacher should consider completing a problem with students, then have the students try some in pairs before having students use them individually.
2. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student groupings.

3. The teacher should consider a formative assessment to determine which students need reviewing, re-teaching or enriching.

Evaluating:

1. The teacher should consider giving students multiple formats to communicate their knowledge. This could be drawing, writing or designing a presentation.
2. Students may need additional time to complete their assignments.

Car Collision Student Sheet

Objective: Determine as much information about your car's motion as possible.

Guiding Question: What types of measurements and calculations are needed to determine your car's velocity?

Measurements:

Calculations:

Position-Time Graph of your car's motion:

Evaluate: After your group has determined velocity and developed a position-time graph for your car, complete the following;

1. Start the car in a different position but going in the same direction: produce a position-time graph.

2. Start the car in the opposite direction: produce a position-time graph.

3. What conclusions can be drawn by comparing these two graphs? Explain.

[Return to Instructional Segment]

Car Collisions: Guiding Questions (Explore)

1. What is displacement, and how did it apply to this investigation?

2. How did your group decide on which measurement units to use?

3. Describe how direction is important in predicting the collision point.

4. How did you determine direction (positive/negative)?

5. How were motion graphs utilized in this part of the investigation?

6. Real-world application: How might kinematics models (equations) be useful outside of the physics classroom?

7. What factors might lead to error in this experiment?

8. What are other questions do you have about this?

[Return to Instructional Segment]

Dropped vs. Launched: Investigation Student Sheet

Objective: your group is to design an experiment that will test the phenomenon seen in the video.

Materials: You will either develop a list of materials needed or will be provided one by your teacher.

Guiding Questions: how can you create your experiment to have the marbles represent the dropped bullet and the horizontally-fired bullet?

Measurements:

Calculations:

Horizontal velocity-time graph:

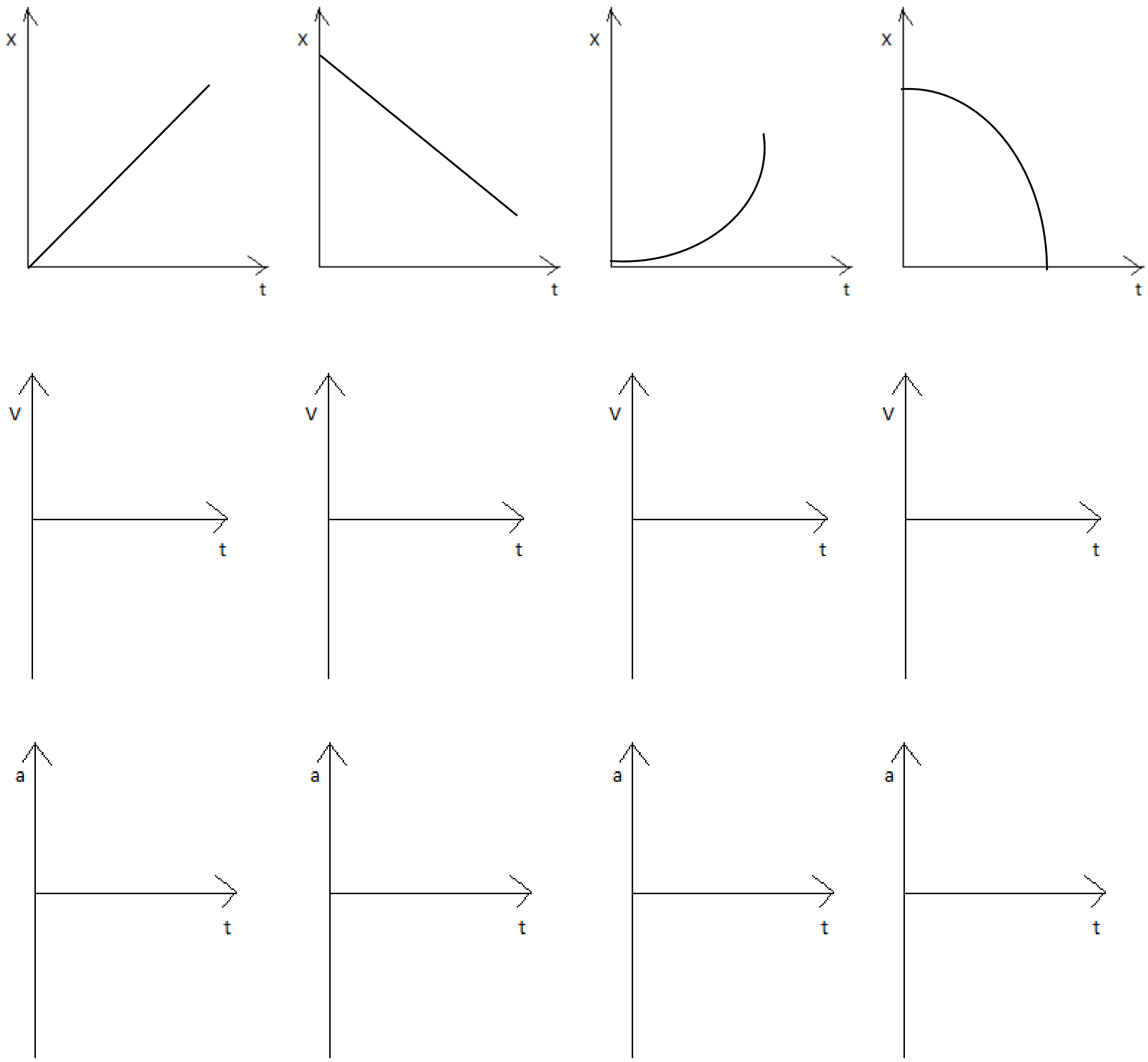
Vertical velocity-time graph:

[Return to Instructional Segment]

Curve Stacks Student Sheet

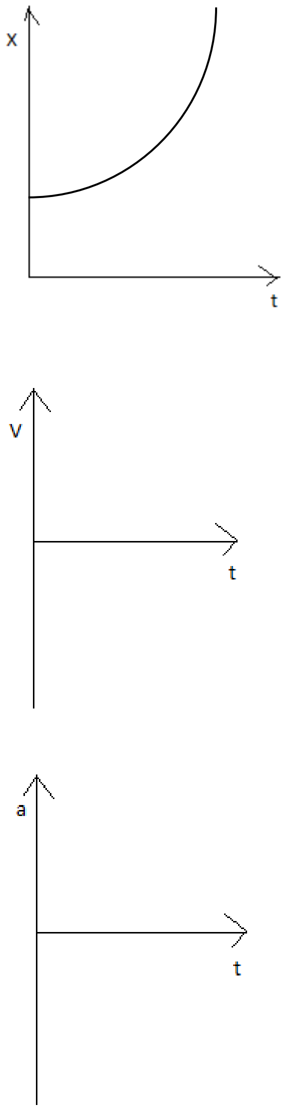
Directions: Sketch a velocity-time graph and acceleration-time graph given the following position-time graphs (The questions are vertical).

1 **2** **3** **4**



Directions: Sketch a velocity-time graph and acceleration-time graph given the following position-time graphs

5



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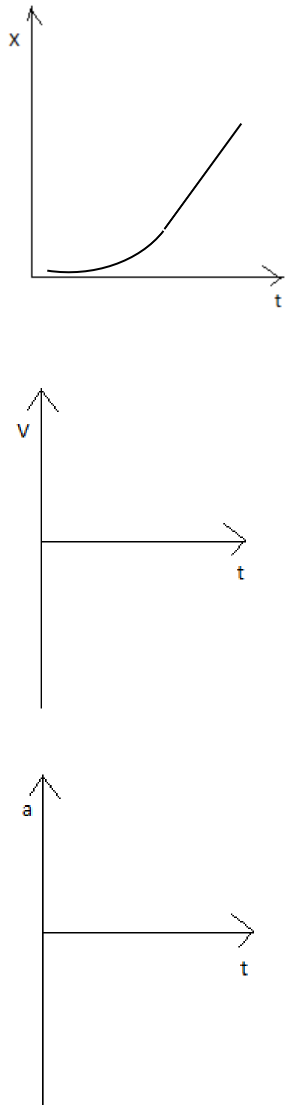

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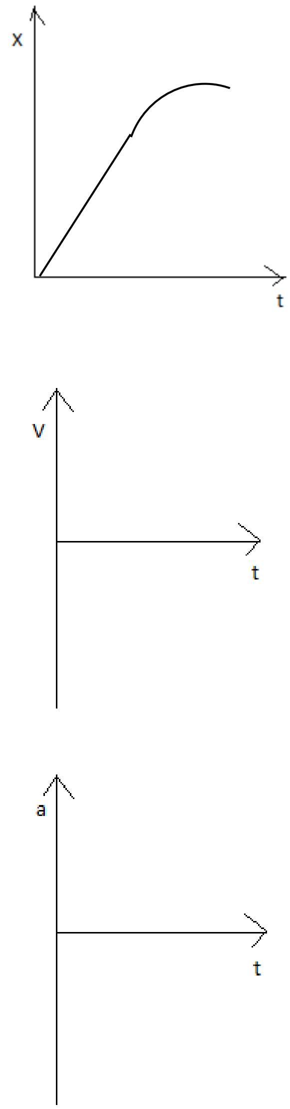

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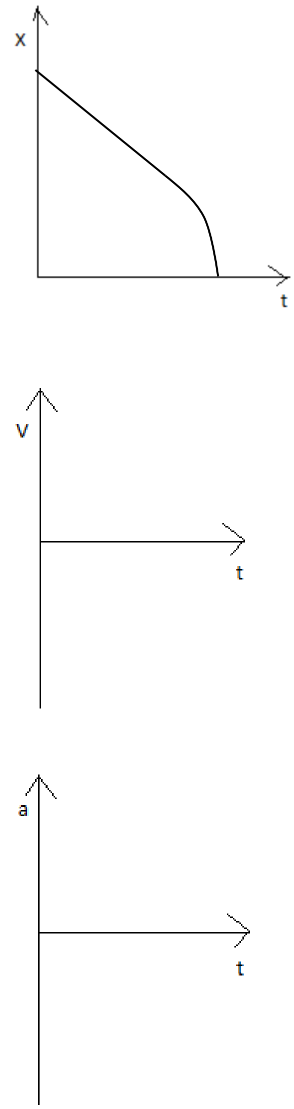
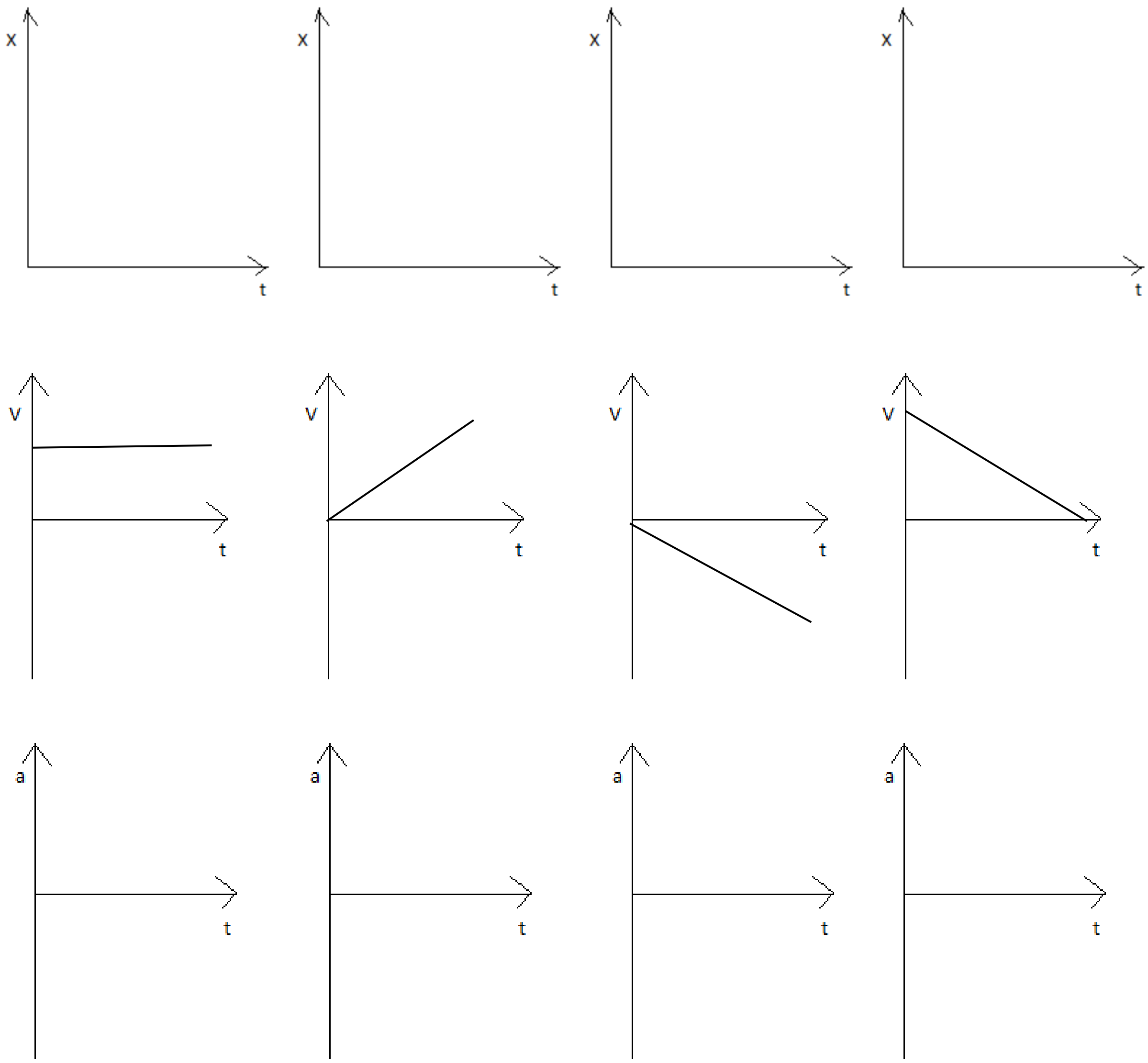
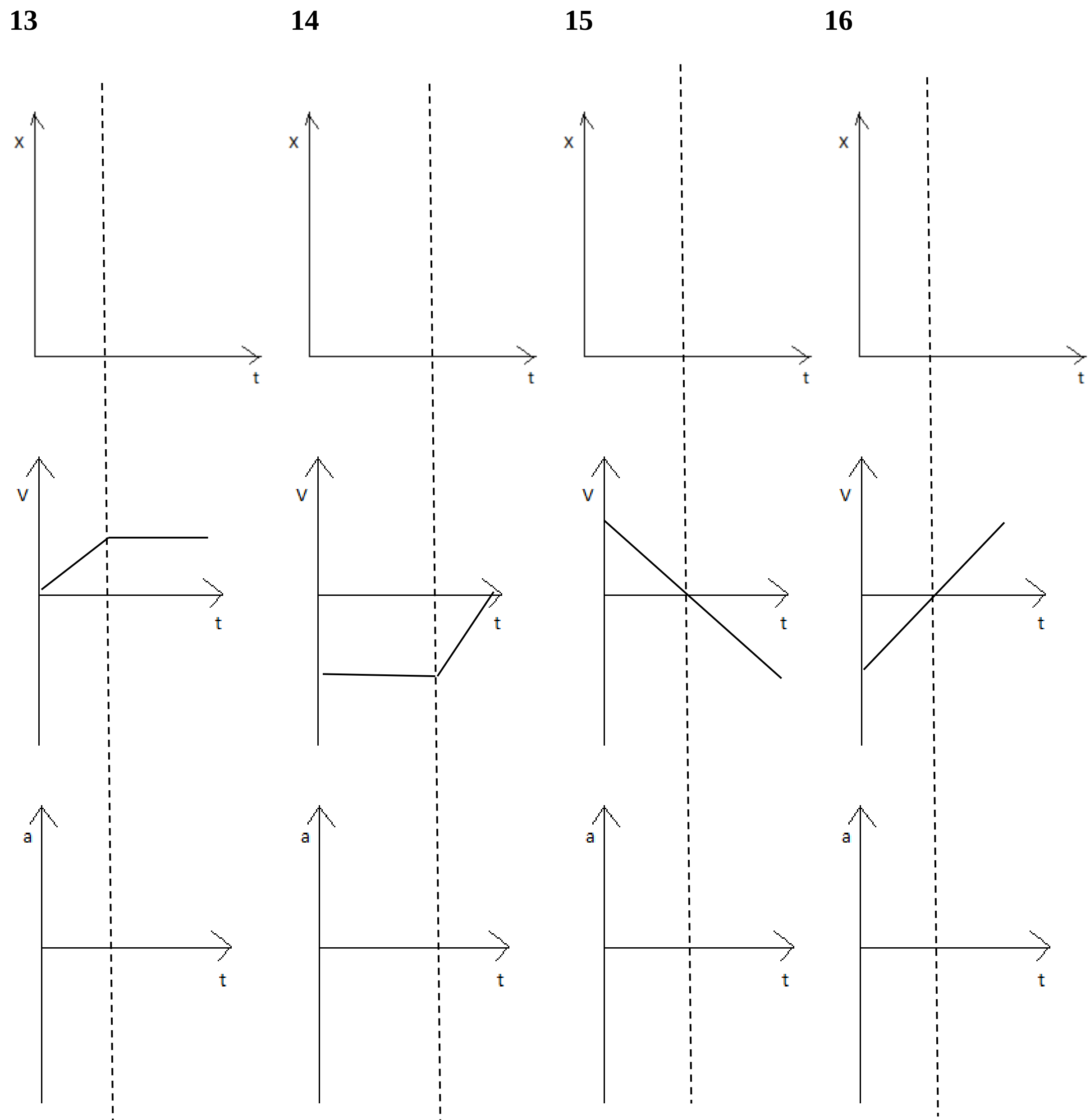


Sketch a position-time graph and an acceleration-time graph for the following velocity-time graphs.

9 **10** **11** **12**



Directions: Sketch a position-time graph and acceleration-time graph given the following velocity-time graphs



17. Choose one set of graphs from questions 1-4 and describe a real-world object and scenario that would reflect the types of motion graphs shown and determined.

18. Choose one set of graphs from questions 5-8 and describe a real-world object and scenario that would reflect the types of motion graphs shown and determined.

19. Choose one set of graphs from questions 9-12 and describe a real-world object and scenario that would reflect the types of motion graphs shown and determined.

20. Choose one set of graphs from questions 13-2 and describe a real-world object and scenario that would reflect the types of motion graphs shown and determined.

[Return to Instructional Segment]

Airplane Delivery Problem Student Sheet

Scenario: A transport airplane must deliver a package by flying over the drop location and releasing the package which drops to the ground. The plane levels at a cruising altitude of 2100 m while traveling at 250 m/s before it makes the drop.

1. Using the kinematic models you used before, determine how the plane must release the package in order to make it land in the drop zone (neglect air resistance).

2. Describe the motion of the package as it falls—treat the horizontal and vertical separately; include diagrams. Produce position-time graphs, velocity-time graphs, and acceleration-time graphs.

3. Combining velocities: With what velocity will the package strike the ground? You must use the vertical and horizontal velocities.

4. If air resistance was considered, how would the motion of the package be different? Explain with diagrams.

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