Lesson 14: Answer Key 1

Design Challenge Organizer Key

14.A Define a design problem within a vehicle-related system by analyzing how transportation technologies impact society to a level that requires attention or mitigation, considering the scale, proportion, and quantity at which the problem is significant. (SEP 1.8, CCC 3.1, ETS2.B.3)

14.B Design and/or refine a solution to a problem related to vehicle safety, considering what is known about cause-effect relationships in smaller-scale mechanisms within the system and prioritizing certain criteria over others to optimize the focus. (SEP 6.5, CCC 2.2, ETS1.C.1)

14.C Use reasonable assumptions or approximations to develop a mathematical model to generate data to predict behavior of a design solution, analyze a system or support an explanation, and meet prioritized criteria. (SEP 2.6, CCC 4.4, ETS1.C.1)

Multiple examples of finished products are included in *Final Product Example Summary*. This work is not intended to show what we think students should produce, as this will depend entirely on your students and the time they spend in class and/or out of class to complete their work. But the responses in this key are based on those examples as a guideline.

Questions 1-3 can be used as a formative assessment to get a sense of where each student is in their understanding of how to connect design problems to physics models and to narrow to one possible problem. If you notice that a group of students has struggled to complete these questions, then they are likely to struggle even more on the rest of the project. For these groups, you may choose to scaffold the project work using case studies: *Case Study #1: Electric Cars*, *Case Study #2: Our Crumple Zone Designs*, and *Case Study #3: Self-Driving Car Ethics*.

The rubrics for questions 3 and 4 are set up to help you support students who have some foundational pieces to reach linked understanding and to support students who have reached linked understanding to organize this understanding. OpenSciEd does not recommend openly targeting and isolating any students from their peers. Instead, consider giving students clear feedback on where they stand and give them the choice to participate in a more-targeted intervention related to each specific question. Alternatively, if your school offers students time outside class to work more closely with teachers or tutors, such as “office hours”, consider intentionally scheduling multiple students for this time so you can work with them together.

3-D Elements Addressed in This Assessment	3	4a	4b	5	6
1.8 Asking Questions and Defining Problems. Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.	X		X		
2.6 Developing and Using Models: Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.					X
6.5 Constructing Explanations and Designing Solutions: Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.				X	X

ETS1.C.1 Optimizing the Design Solution: Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade offs) may be needed.			X	X	X
ETS2.B.3 Influence of Engineering, Technology, and Science on Society and the Natural World: New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.	X		X		
2.2 Cause and Effect: Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller-scale mechanisms within the system.		X		X	
3.1 Scale, Proportion, and Quantity: The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	X				
4.4 Systems and System Models: Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.					X

Step 1: Brainstorm real problems that affect people that we care about.

1a. What is something in our community that might put some people more at risk than others because of cars or driving? *This could be a place, a policy, a technology or even a lack of technology.*

1b. What is something that has made you feel safer when you are driving, walking, or taking public transit?

From your personal experience or research, brainstorm with your team some answers to 1a and 1b. Jot down notes on each problem below. *If you did a home interview, share those notes with your team as well.*

- There is an intersection with three different roads coming together, and it's also a bike path. When I ride my bike through there I always have to wait for a long time before I feel safe crossing.
- People go really fast in front of the school.
- My friend's car is so old it doesn't have an airbag.
- I heard that crash test dummies are made to be like men, which makes women less safe.
- I heard that AI makes decisions that make the owners of the AI company safer.
- Speed limits on highways in our state are, like, 85 mph.

- My car has an automatic feature that stopped the car one time when I was on my phone
- My mom always drives under the speed limit no matter what. and it's annoying but it feels safe.
- My phone has a setting where it literally won't let me use it while driving.

Step 2: Connect to physics to narrow to a solvable problem.

2. Choose 3-4 possible problems from question 1 that seem connected to physics in our unit. For each problem, note which models or science ideas listed below are connected to it. If you cannot come up with any physics connections for some problems, make note of that also. *If you are truly stuck, your teacher can provide you with case studies that may help you narrow your focus.* Our models so far include

i. velocity graphs, reaction distance, braking distance

ii. force and changes in motion while braking, crumpling, or stopping

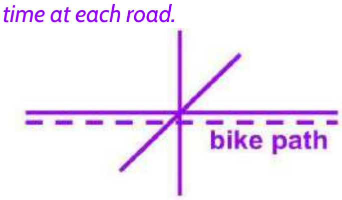
iii. conservation of momentum

AI companies - not sure
People go fast, Speed limit - i. velocity graphs, reaction distance, braking distance
Cycling - i. velocity graphs, reaction distance, braking distance or ii. force and changes in motion
Airbag vs. no airbag - ii. force and changes in motion
Phone disable - i. velocity graphs, reaction distance, braking distance

3. Decide on a single problem that matters to your team and your community and that seems possible to solve with ideas related to our physics models. Then below, **describe or draw the problem you decided on with your team.** The questions in *a* and *b* may help you prioritize. Discuss them as a group before or after you choose one problem.

a. How widespread is the problem? How often does it occur? In what place(s) does it occur?
b. Identify details to help your team narrow to a specific location, policy, or safety system. *Where and when in our community does this problem occur? Who does it affect and how?*

Rubric for question 3

	Foundational Pieces	Linked Understanding	Organized Understanding
3-D elements	**Look for students to** Define a design problem by analyzing how transportation technologies impact society.	**Look for students to** Define a design problem by analyzing how transportation technologies impact society and acknowledging the scale of the problem.	**Look for students to** Define a design problem within a vehicle-related system by analyzing how transportation technologies impact society to a level that requires attention or mitigation, considering the scale, proportion, and quantity at which the problem is significant. (SEP 1.8; CCC 3.1; ETS2.B.3)
Example	*We want to focus on cycling or AI companies, but we don't know how to connect either one to physics.* *a. Cycling is pretty common, especially in the summer. I don't know when bike accidents are most common.* *b. Cycling affects people who bike, but AI could affect anyone. It doesn't seem like AI drivers are very common yet, but neither is cycling.*	*We want to focus on cycling and bike paths. The bike path that goes by the school is too slow and dangerous for cyclists.* *a. Cycling affects people who bike. I've seen three bike accidents riding to and from school so far this year. I guess the scale is big because the bike lanes go across the entire city.* *b. We think about focusing on the bike path near school because there are places where cyclists have to wait a long time.*	*We're focusing on the intersection of Park, Lafayette, and 16th because there are too many roads intersecting at one place, and people have to wait a long time at each road.*  *This problem is just in one intersection, but we think the impact could be big. Cycling is a popular way to get around in our city, but some places seem pretty unsafe and people could drive instead of cycling from just one bad experience. We think that by focusing on just one intersection we could expand safe cycling in a bigger way.*
Feedback	*Linking*	*Organizing*	*Extending*

	First, recognize the progress of students who targeted specific ways that specific technologies or policies can impact safety. If any of the problems that the students identified in question 2 or question 3 can be easily connected to physics models, point this out. If giving feedback between day 1 and day 2 of L14, write, *This one seems worth pursuing. Which physics model connects: i, ii, or iii?* If the problems that some students identified cannot be easily connected to physics models, consider urging students to look at one of the case studies as a scaffolding tool. Write, *These are great, but they look hard to connect to physics. If you want, I have a few case studies with data that you could choose from.*	First, point out the potential connections to physics models that exist in a group's design problem, then encourage them to try to articulate details about the scale or quantity of the problem. If giving feedback between day 1 and day 2 of L14, write, *Where exactly are you planning to target your solution? Being specific will help your solution be more impactful.* Help students to articulate that the scale or quantity of the problem or solution can be significant if they're able to target a solution in a useful way. In other words, try not to equate *significance* with *scale*.	Encourage students to focus their design problems specifically and locally, if possible. To facilitate this, encourage students to take their own photos of objects or areas that are relevant to their problem or to find relevant photos online using online street mapping software or other research. Encourage students to browse the Key Words Spreadsheet at https://docs.google.com/spreadsheets/d/1EqONf6yEYqLFZZn4LUcmzFQeJNATscIE9rWCmN-xNyO/copy to hunt for relevant sources that could help them make future project steps more meaningful.

Step 3: Prioritize criteria, then design a solution.

4a. What might be causing this problem? What are the effects of the problem that might impact safety? Use evidence from experiments or readings to help you identify these cause-effect relationships in the system where your problem exists.

4b. Use your answer to 4a to prioritize criteria to optimize your solution:

- **Criteria:** Who or what will you prioritize? What do you want the solution to accomplish?
- **Trade-offs:** Who or what may be negatively impacted by your solution? What might you have to give up?

NOTE: While giving feedback between days 2 and 3 of L14, study each group's prioritized criteria and cause-effect details here alongside their proposed design solution ideas in question 5. While the feasibility of students' design solutions isn't being assessed, students do need to show that their solution considers prioritized criteria and trade-offs.

Rubric for question 4

	Foundational Pieces	Linked Understanding	Organized Understanding

3-D elements	**Look for students to** Identify specific criteria for a design problem related to cars or driving (SEP 6.5, ETS1.C.1)	**Look for students to** Identify prioritized criteria for a design problem related to cars or driving, considering cause-effect, (SEP 6.5, CCC 3.1, ETS1.C.1)	**Look for students to** Design and/or refine a solution to a problem related to vehicle safety, considering cause-effect relationships suggested or predicted by smaller-scale mechanisms within the system and prioritizing certain criteria over others to optimize the focus. (SEP 6.5; CCC 2.2; ETS1.C.1)
Example	*a. Cyclists have to wait a long time at the intersection for a time to cross.* *b. We will prioritize cyclists. We want them to be safer on the roads. Cars are negatively affected by speed humps because it's annoying.*	*a. It's a busy intersection, so there's always a lot of traffic waiting. Cars are going fast because it's a big road.* *b. Our top criterion is to keep cyclists safe. Bicyclists are more at risk because they don't have a car around them to keep them safe.*	*a. Many roads come together at once, including the bike lane. In general, this currently tends to slow down traffic already because people have to wait for the light. This means it would make everyone much safer to slow down slightly earlier, without being too inconvenient.* *b. Our top criterion is to keep cyclists safe. Bicyclists are more at risk because they don't have a car or a crumple zone around them to keep them safe, so we need to protect them by making collisions less likely. We can do that by decreasing car speed.* *The big trade-off that would affect most people is just being inconvenienced, but this isn't actually a bad thing if it just made more people ride instead. You might make some enemies out there, but haters gonna hate.*
Feedback	*Linking* First, acknowledge any specific evidence or details that students identified in part 4a. Then, to bring out cause and effect, ask students *why*. If giving feedback between days 2 and 3 of L14, write "*because _______*" to encourage students to fill in the blank with details about cause-effect reasoning.	*Organizing* If a group's design problem can be made more specific, ask questions about scale to help them narrow it down. Say, *What specific example of that idea can you think of? Is there a [part of the car / intersection / part of town] where you know that happens?* If giving feedback between days 2 and 3 of L14, prompt for details about trade-offs and perspective. Write, *Who does this protect? Who does it leave out?*	*Extending* Push students to find a scale where their solution can have real local impact. Direct students to question 5 and support them in developing their own ideas about what sorts of solutions could actually make a difference. If giving feedback between days 2 and 3 of L14, consider directing students back to the https://docs.google.com/spreadsheets/d/1EqONf6yEYqLFZZn4LUcmzFQeJNATscIE9rWCmN-xNyO/copy now that they have more familiarity with the topic. Write, *Check out articles on … in our Key Words Database.*

5. Work with your team to design 1-2 possible solutions that meet the criteria you set in question 4b. Describe or draw below the solution that you decided on with your team.

Try not to harshly judge the feasibility of students' solutions. Your focus should be on connecting those solutions to the prioritized criteria and cause-effect details in question 4.

If you think that feasibility or real potential impact matters for your class, consider giving students a chance to present their work more formally to one another, using a co-created rubric to evaluate one another's work. As a class, students might identify the solutions with the most potential to impact change and provide suggestions for how to advocate for these solutions (city hall, parent groups, etc.).

See examples of finished products and summaries in *Final Product Example Summary*.

Step 4: Model using physics, then present your solution.
6. Look back at your answers to question 2 in step 2. Then, use mathematical models that we have developed in our unit to explain what makes the problem dangerous or how your solution would help make people safer. **Remember the criteria you identified in question 4b. If you can, focus your modeling on these criteria to optimize your solution.**

NOTE: Assumptions and approximations are often required when modeling, especially when we have limited evidence. What reasonable values might you try in your modeling to help you show or explain your problem and/or your solution?

Examples of how physics might be integrated into different types of projects can found in *Physics Models Used in Design Solutions*.

Encourage students to make up reasonable values to use in their quantitative models, especially if they can contrast two values to illustrate a point.

For i. velocity graphs, reaction distance, braking distance

- **For Linked Understanding:** Students might model *distance = speed • time interval* with relevant speed limits to connect reaction time to reaction distance (L3).
- **For Organized Understanding:** Students might use speed-time graphs of changing speed to calculate reaction distance and/or braking distance (L4).

For ii. force and changes in motion while braking, crumpling, or stopping

- **For Linked Understanding:** Students might use *force* • Δt = *mass* • Δv to explain qualitatively that extending the time in a collision can decrease the force (L9, L11).
- **For Organized Understanding:** Students might estimate or research reasonable values to model *force* • Δt = *mass* • Δv in two related scenarios, such as with and without their design solution (L9, L11).

For iii. conservation of momentum

- **For Linked Understanding:** Students might use *conservation of momentum* to explain qualitatively that a larger or faster vehicle can cause more damage to other vehicles in a collision (L6).
- **For Organized Understanding:** Students might estimate or research reasonable values to model *conservation of momentum* in a collision in two related scenarios, such as colliding with vehicles of greater or lesser mass or speed (L6).

7. With your team, present a summary of the problem you identified alongside your solution. This can be in a slide deck, an essay, or another format you choose. Your format should allow you to include the following sections:

- **The Problem -** Summarize in 1 sentence (see question 3).
- **Our Solutions -** Describe or draw 1-2 solutions (see question 5).
- **Supporting Evidence and Criteria -** Use evidence and reasoning to describe the goal of your solution: "*Our solution should ...*"(see questions 4a and 4b and other resources for evidence).
- **Physics -** Show modeling related to i, ii, or iii in question 2, using reasonable values (see question 6).
- **Trade-offs -** Who or what may be negatively impacted by your solution? What did you have to give up? (See question 4b.)

See examples of finished products and summaries in *Final Product Example Summary*.