Newton's Laws

Governing Rules Series

Instructor's Guide

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Developed by the Teaching and Learning Laboratory at MIT
for the Singapore University of Technology and Design

Introduction

When to Use this Video

- In Phys 101. This video can be viewed in a lecture or recitation/discussion section, or can be assigned for students to watch outside of class. If the class has prior physics experience from other courses, the video should be assigned to be watched before Lecture #10. For a class with no prior experience, it can be assigned before Lecture #11.
- Prior knowledge: It is assumed that students have been introduced to Newton's Laws in the past, but not that they have necessarily spent a significant amount of time with them.

Key Information

Duration: 9:06
Narrator: Prof. Deepto Chakrabarty
Materials Needed:
• Paper
• Pencil

Learning Objectives

After watching this video students will be able to:

- Recognize Newton's Laws.
- Attribute physical events to the action of a particular law.

Motivation

- Most existing videos use more contrived situations (as opposed to real-world situations) to explain Newton's Laws, or use more colloquial approaches to the topic. This video uses Newton's Laws with precise terminology to describe real-world physical situations in depth.
- This video also frequently deals with two-dimensional movement, whereas most resources deal with Newton's Laws in a single dimension.
- Attention is given to typical misconceptions in the first and third laws. When it comes to the law of inertia, students often forget that vertical and horizontal motion are independent. This fact is explicitly pointed out in several places in the video. In the third law section, most of the cases involve objects of differing masses, allowing viewers to see how the law of equal and opposite reactions does not mean equal and opposite movement.

Student Experience

It is highly recommended that the video is paused when necessary so that students are able to examine the situations shown.

During this video students will imagine where a particular law would apply in a given situation.

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Video Highlights

This table outlines a collection of activities and important ideas from the video.

Time	Feature	Comments
0:44	Prerequisites and Objectives	
1:05	First views of crash tests and ice skaters	
1:47	First Law segment	This segment shows pieces of engine flying out of a car, headlights leaving the car, a figure skaters' vertical throw, and a vertical spray of liquid.
3:58	Second Law segment	This segment includes an ice skater jump, cars being slowed during a crash, a discussion of the independence of X and Y during a skating video, mirror rotation during a crash, and cars rotating around each other with an overhead diagram.
6:23	Third Law segment	This segment includes a horizontal throw while skating, an example with differing vehicle masses, and a discussion of why an object might not seem to move during a crash.
8:22	Review and wrap-up	

Video Summary

This video examines a set of physical situations (car crashes and figure skating) and describes elements of them in terms of Newton's Laws. Each law is examined in a separate "chapter" of the video, with replays and voiceovers emphasizing particular points.

Phys 101 Materials

When appropriate, this guide is accompanied by additional materials to aid in the delivery of some of the following activities and discussions.

Pre-Video Materials

1. Have students write down an example of a situation that makes the applicability of Newton's Laws difficult to see. A typical example given in textbooks is pushing a shopping cart, which slows down to a halt when the force is removed. If they are having trouble, suggest that they pick a particular law first. Once everyone has an example, have students get into groups of two or three to compare. Each group will pick one example to share with the class.

This question is designed for use at the beginning of class, perhaps as a "do now" activity (written on the board for the students to do as soon as they arrive in class).

2. Ask students the following question: Given that an object cannot exert a net force on itself, what force pushes us off the ground when we jump? Ask them to consider whether the "given" above is actually true. If there is sustained debate on the topic, ask the students to consider objects or people in deep space.

This question is well-suited to a discussion section with a small number of students. It does have the potential to turn into a "fishing expedition" (where it appears that the teacher is "fishing" for an answer and the students do not have it) if let go for too long without an answer. For that reason it may be best saved for the last few minutes of class. That way it can be turned into an at-home challenge problem at the end of class time.

Post-Video Materials

1. Have students get into groups of 2 or 3. Ask them to pick a physical situation to describe in terms of Newton's Laws. Their group will brainstorm (in writing) all the places in that situation where one might see the laws at work, in a manner similar to the video. They should come up with as many examples as they can in five minutes, and make sure they have at least two examples for each law.

2. As an activity for a discussion section: have students prove that forces internal to a system do not impart a change in momentum to that system. If they students are having trouble, ask them to explain what "internal to the system" means.

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There are pre-made PowerPoint® slides for these questions in the appendix of this document, as well as in the "Clickers.pptx" file.

3. Car Tumble (Appendix A1-1 through A1-4)

This problem has an extra slide for set-up (necessary), and a few extra follow-up slides with slightly different questions (recommended).

The effectiveness of this problem relies on students' tendency to pick a reference frame without being explicit about it. To draw out this issue, the two follow-up slides should be used immediately after voting on the first slide, without discussing the first one and (if using clickers) without seeing the votes for the first one. Students may want to go back and change their answer; holding a re-vote is fine. Allow the students to come to their own answers after seeing all three slides.

4. Accelerometer (Appendix A2)

Useful questions to ask during the discussion include:

- How might you build this force meter? (This question is especially useful if some students are having difficulty picturing the device. If they ask you "What is this force meter?" or "How does it work?", throw the question back to the class.)
- How do you want your force meter calibrated? (This question is likely to arise during discussion, as different students pick different sensible answers for different reasons.)

5. Dog and Wagon (Appendix A3)

This problem was developed by Assessing to Learn Physics (http://a2l.physics.umass.edu/library/item_0023). Further discussion of the problem can be found there.

6. The Classic (Appendix A4)

This problem is the classic bowling-ball-and-pins question in a different context. As with that question, the issue of differing masses and differing accelerations can confuse students. If some have difficulty with the idea of a fluid raindrop experiencing a force, ask them to consider a solid hailstone hitting the umbrella instead.

7. Third Law Pairs (Appendix A5)

While many of these items are indeed equal and opposite, none of them are Third Law action/reaction pairs. Asking students what the "reaction" is to a particular force may help to show why none of the choices are good. This question also serves to remind students that "None of the above" is not a throw-away option.

8. Citrus Tug of War (Appendix A6)

If students simply answer that one side should "pull harder," point out that there are Third Law pairs at work here, and that furthermore the tension in the rope must be the same along the entire rope (something they have likely heard but forgotten).

You may eventually have to ask "What other forces are at work here?" This gives the answer away, so avoid this question until discussion is starting to stagnate.

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Additional Resources

Going Further

A supplement to this video is included in the Going Further folder. This set of PowerPoint® slides covers the adaptation of Newton's Third Law to a rotational format, introducing the idea of equal and opposite torques. Because such torques must be calculated from the same reference point, this idea can be tricky for students encountering it for the first time. These slides run through a simple example (using a car crash), showing why a naive approach fails and how to properly approach the problem. The "notes" section of the PowerPoint® includes a suggested script for teaching the topic.

References

An embarrassment of riches is to be found in physics education research literature when it comes to student misconceptions in forces. The references below are good introductory materials and cover a variety of force-related topics. The first reference is a resource letter that lists over 200 papers, many of which are centered around introductory mechanics.

- McDermott, L., Redish, E. (1999) RL- PER1: Resource Letter on Physics Education Research. *American Journal of Physics. 67*(9), 755-767.
- Viennot, L. (1979) Spontaneous reasoning in elementary dynamics. *Eur. J. Sci. Educ. 1*(2), 205-222
- McCloskey, M., Caramazza, A., Green, B. (1980) Curvilinear motion in the absence of external forces: Naive beliefs about the motion of objects. *Science. 210*, 1139-1141
- Clement, J. (1982) Students' preconceptions in introductory mechanics, *Am. J. Phys. 50*(1), 66-71
- Maloney, D. (1984) Rule-governed approaches to physics: Newton's third law. *Phys. Educ. 19*(1), 37-42
- Halloun, I., Hestenes, D. (1985) Common-sense concepts about motion. *Am. J. Phys. 53*(11), 1056-1065
- Thornton, R. (1997) Conceptual dynamics: Following changing student views of force and motion. *AIP Conf. Proc. 399*, 241-266

For students who would like to learn more on their own, and who are looking for a more technical video, Khan Academy has a section on force and Newton's Laws. The videos begin at the following link:

- http://www.khanacademy.org/video/newton-s-first-law-of-motion?playlist=Physics

MIT's OpenCourseWare site includes an introduction to forces. It may be a good resource for students who want to learn more on their own.

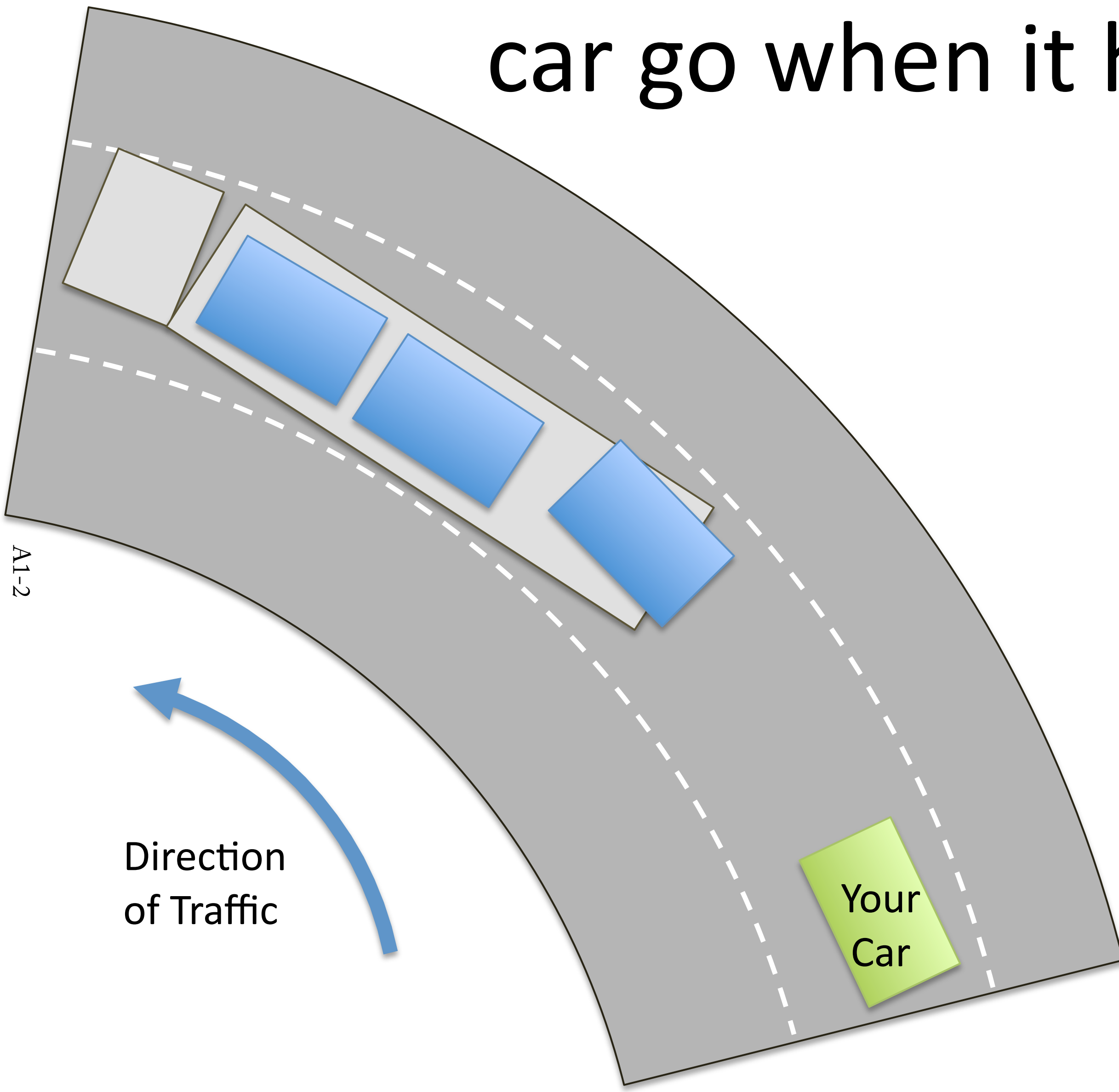
- Lewin, Walter. *8.01 Classical Mechanics, Fall 1999*. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu (Accessed 22 Dec, 2011). License: Creative Commons BY-NC-SA
- The videos stored at this location are particularly useful: http://ocw.mit.edu/courses/physics/8-01sc-physics-i-classical-mechanics-fall-2010/concept-of-force/

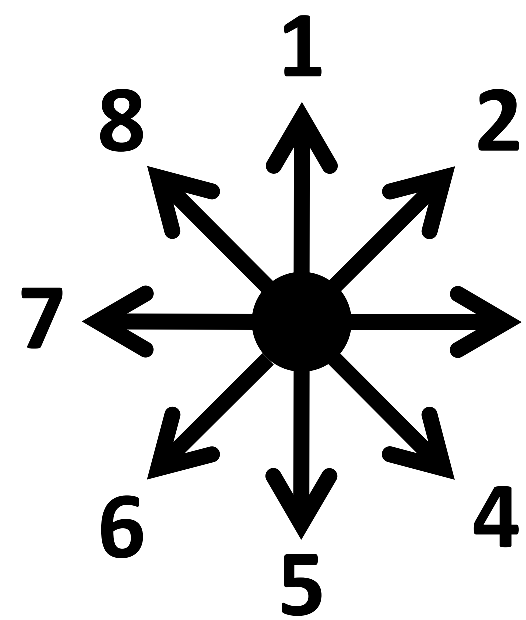
Use this scenario for the next set of problems.

You are driving on the highway behind a “car carrier” truck (see picture).

As the highway turns to the left, the *last car falls off the truck.*

Which direction does the falling car go when it hits the road?

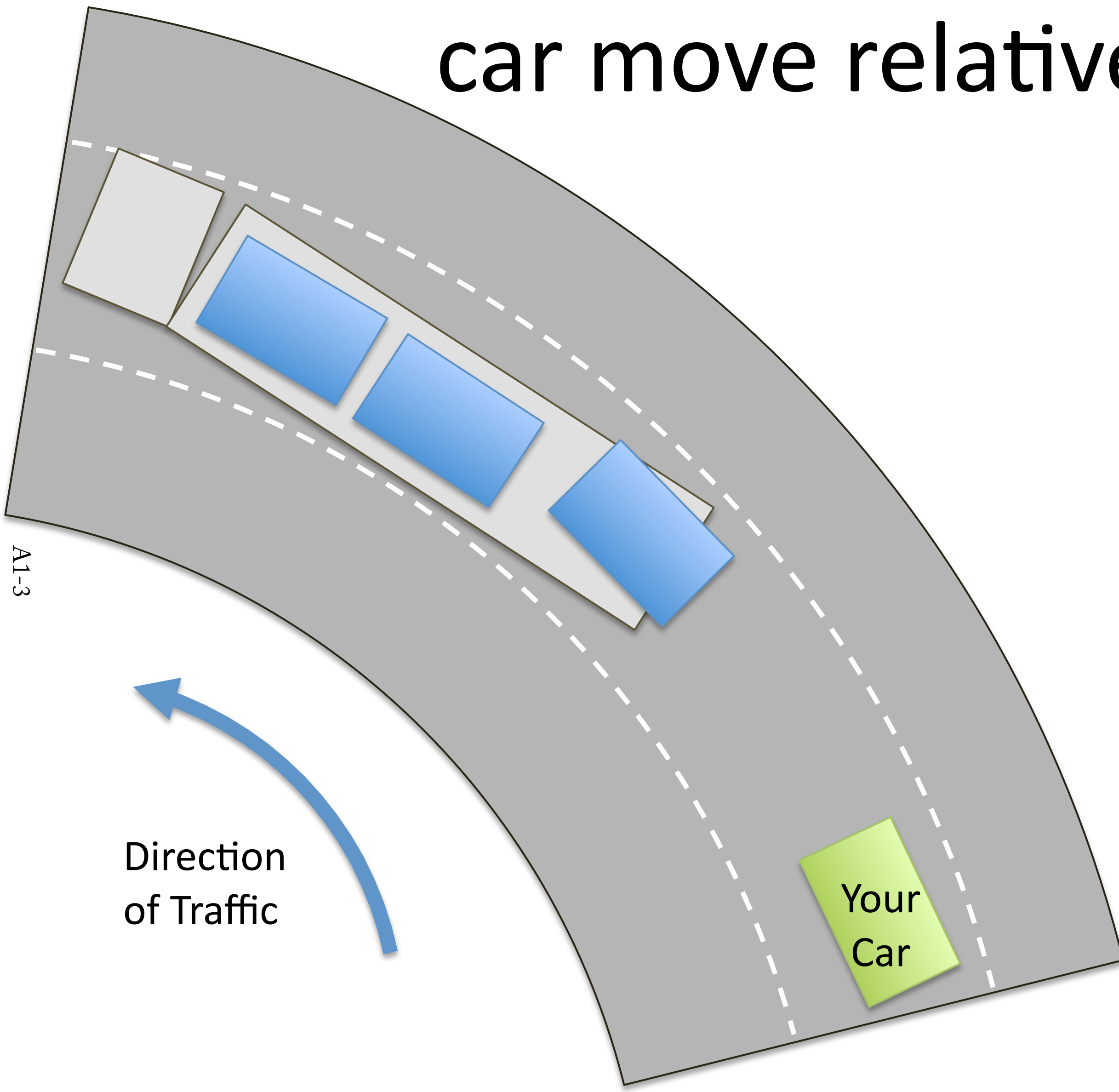


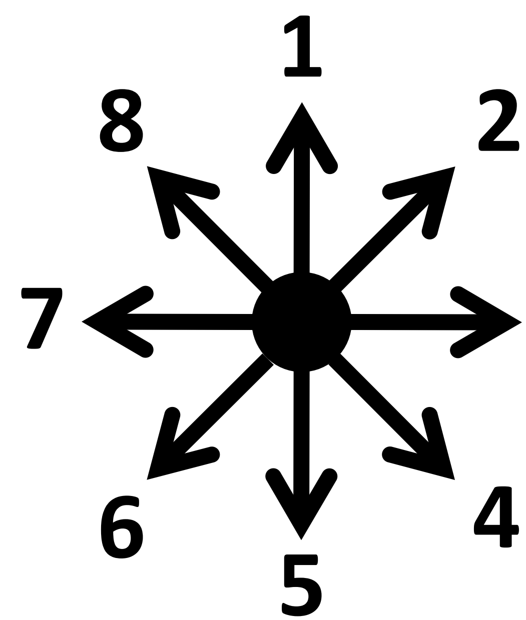


9: Around the curve in the direction of traffic

0: Other

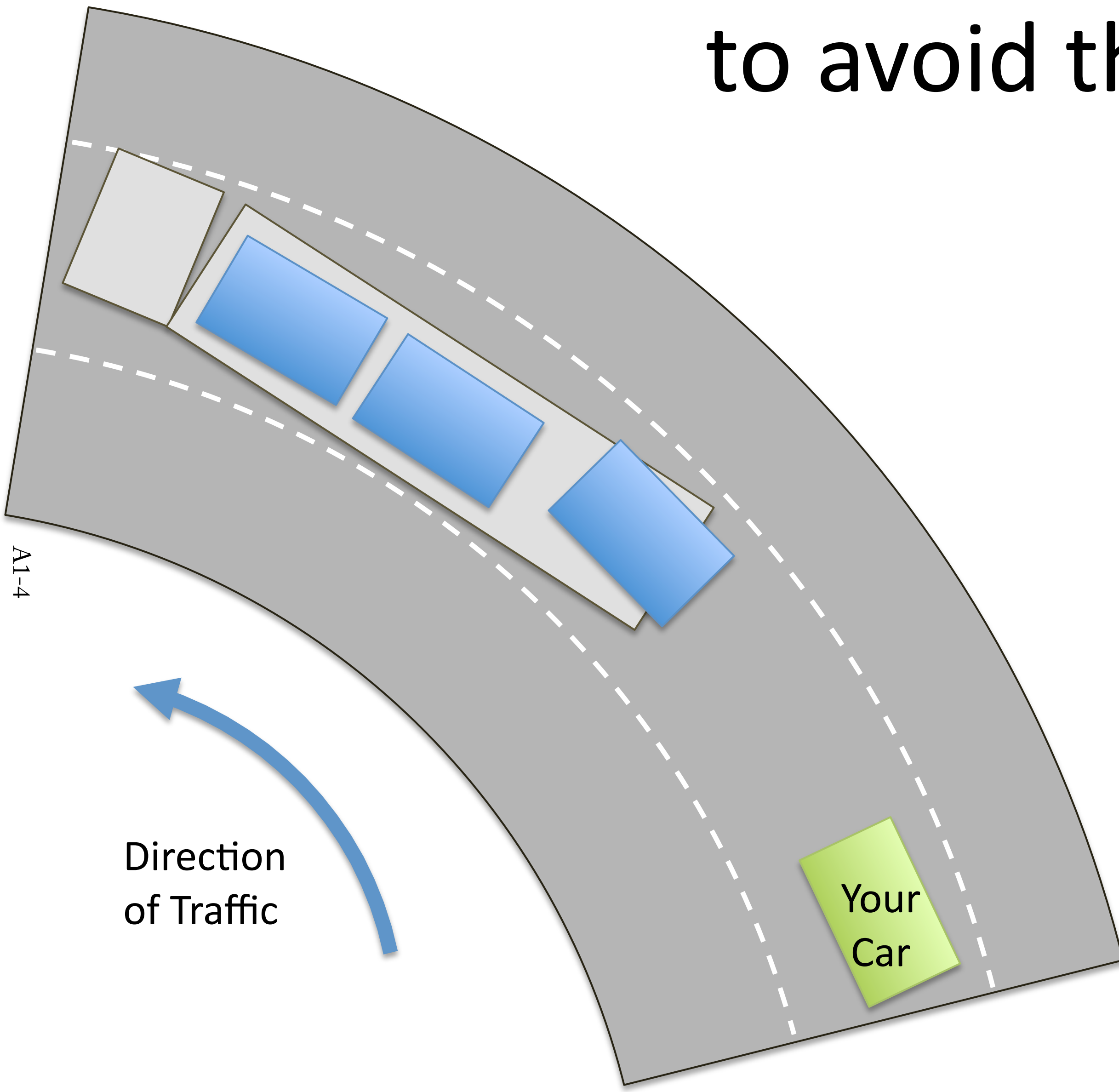
Which direction does the falling car move relative to your car?

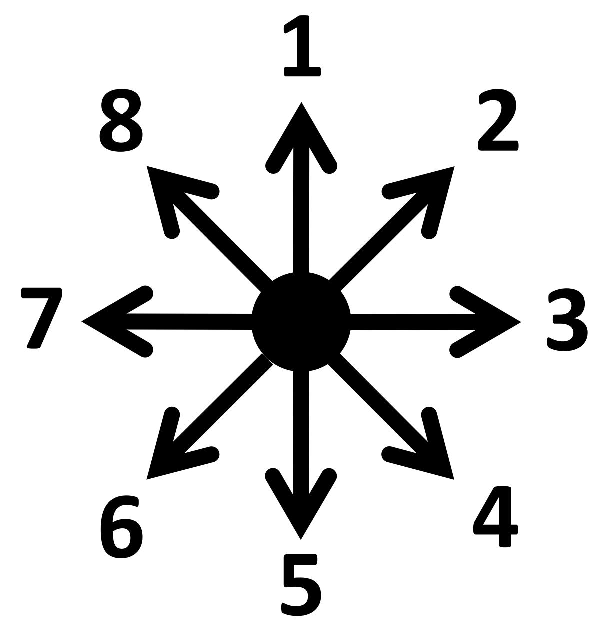




9: Around the curve in the direction of traffic
0: Other

Which direction should you steer to avoid the falling car?





9: Around the curve in the direction of traffic

0: Other

You are carrying a force meter (a 1 kg mass on a set of springs) on a roller coaster to conduct some experiments. As the coaster makes its long climb at the beginning of the ride, you are rising vertically at a constant speed of 1 m/s. What will your force meter read?

① 10.8 N down

② 9.8 N down

③ 8.8 N down

④ Just more than zero Newtons down

⑤ Zero Newtons

⑥ Just more than zero Newtons up

⑦ 8.8 N up

⑧ 9.8 N up

⑨ 10.8 N up

⓪ Other

A child is walking along the sidewalk at a constant speed of 1 m/s while pulling his dog sitting in a wagon. The dog has a mass of 30kg and the wagon weighs 50N. If the child pulls the wagon with a force of 60N at an angle of 30°, what is the frictional force exerted by the wagon on the dog?

① 0N
② 2N
③ 5N
④ 10N
⑤ 15N
⑥ 20N
⑦ 32N
⑧ None of the above
⑨ Cannot be determined

Problem courtesy of A2L: Assessing-to-Learn Physics (http://clickercentral.net/)

A raindrop falls on an umbrella. How does the magnitude of the force that the umbrella feels compare to the force that the raindrop feels?

① The force on the raindrop is much bigger.
② The force on the raindrop is a little bigger.
③ The forces have the same magnitude.
④ The force on the umbrella is a little bigger.
⑤ The force on the umbrella is a much bigger.
⑥ Impossible to tell.

In this drawing, identify a pair of forces that are a Newton's Third Law pair.

① The left team pulling on the right team, and the right team pulling on the left team.

② The normal force on the left team, and the force of gravity on the left team.

③ The force of friction on the left team, and tension from the rope pulling on the right team.

④ The right team pulling on the rope, and the left team pulling on the rope.

⑤ None of the above.

In this picture an orange and a lime are having a tug-of-war. Free-body diagrams are drawn below.

If all these forces are equal, how is it possible for one fruit or the other to win the tug-of-war?