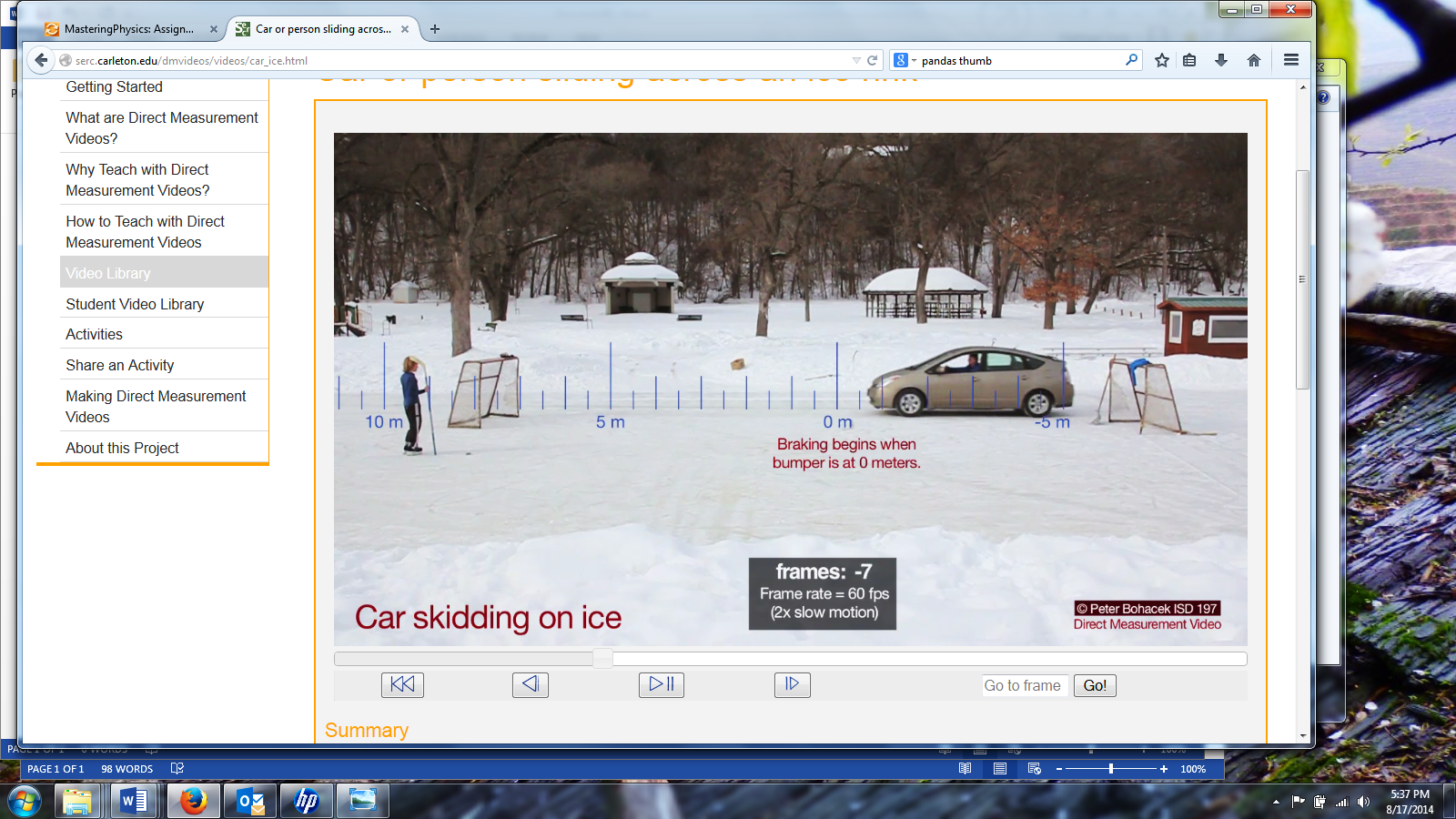
**Car Sliding across an ice rink**

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1. Carefully watch the Car Sliding across an ice rink video. What are a few things that you notice?
2. How fast is the car going before the brakes are applied?
3. How far does it go after the brakes are applied?
4. How much time does it take the car to stop once the brakes are applied?
5. Why does it take so long? Is there some object that is pushing the car forward? Is there some residual force from the engine? What property of the car makes it continue to move forward even when the net force on it is backwards?
6. What is the direction of the net force on the car after the brakes are applied? How do you know?
7. What is the direction of the motion of the car after the brakes are applied but before it comes to a stop?
8. What is the average acceleration during that time interval (when the brakes are being applied)?
9. Average velocity can be found two ways. Solve for the average velocity (during braking) using both methods and then compare the results.
   1. vavg = displacement/time
   2. vavg = (final velocity +initial velocity)/2 *NOTE: This equation is valid when the acceleration is constant.*

**Uncertainty**

The two numbers that I got above when I calculated the average velocity are not exactly the same. Yet, we can still ask if the two values agree, that is, do the range of values for the two numbers overlap when we consider the uncertainty of each number. All measurements have some uncertainty. In this case there is some uncertainty in the measurement of distance and time.

1. Estimate the uncertainty in your distance measurements. Express your answer in meters.
2. Estimate the uncertainty in your time measurements. Express your answer in frames and in seconds.
3. Recalculate vavg above using both methods, but this time add or subtract your uncertainty to each factor (displacement and time) to find the largest spread possible. Using equation 1 above, vavg will be the highest when the displacement is large and the time is small.

*For example if previously you had found that the car travelled 7 meters in 52 frames your value for vavg would have been:*

*(7 m / 52 frames) x (60 frames / 1 second) = 8.08 m/s*

*If you think your displacement uncertainty is 0.1 m and your time uncertainty is 2 frames then you would re-solve for vavg in a way that produce the most spread, i.e.,*

*(7 + 0.1 frames ) / (52 – 2 frames) x (60 frames / 1 second) = 8.52 m/s this is your HIGH value*

*(7 – 0.1 frames) / (52 + 2 frames) x (60 frames / 1 second) = 7.67 m/s. this is your LOW value*

1. When you compare the ranges of vavg using equation 1 and equation 2 above, do the ranges overlap?

**Forces & Friction**

1. Why is the car slowing down?

My guess is that most of you said that the car is slowing down because the brakes were applied. That’s a good step, but in physics class we’ll think about it in a little different way. Newton’s first law says that nothing can change its velocity unless there is a net force on it. *Note: The net force on an object is just the sum of the forces on an object. If you add up all the forces on an object and the sum is zero then the object will maintain its velocity (both speed and direction).*

You might be tempted to think that the brakes provide a net force, but the brakes are part of the car itself and as such they can’t exert a net force on the car. It’s the same principle as the old phrase, “you can’t pull yourself up by your bootstraps.” Because if you try to pull up on your bootstraps, you’ll invariably push your boots down \*harder\* with your feet, so the net force will stay at zero.

1. What *object* outside of the car is forcing the car to come to a stop? What is the direction of that force?
2. The force of friction, Ffriction, is equal to the normal force, n, times the coefficient of friction, . Since the sum of the horizontal forces, Fx, must be equal to the horizontal acceleration, ax, you should be able to solve for  even if you don’t know the mass of the car. What value do you get for ? *Note: since the tires both roll and slide we’ll just calculate an average  without trying to tease out the difference between kinetic and static.*
3. What could you change about the situation to increase that force on the car?

**Brakes**

1. You’ll notice that the front wheel of the car stops and starts rotating a few times as the car is coming to a stop. That is because the car has an antilock brake system. What is the advantage of an antilock braking system?