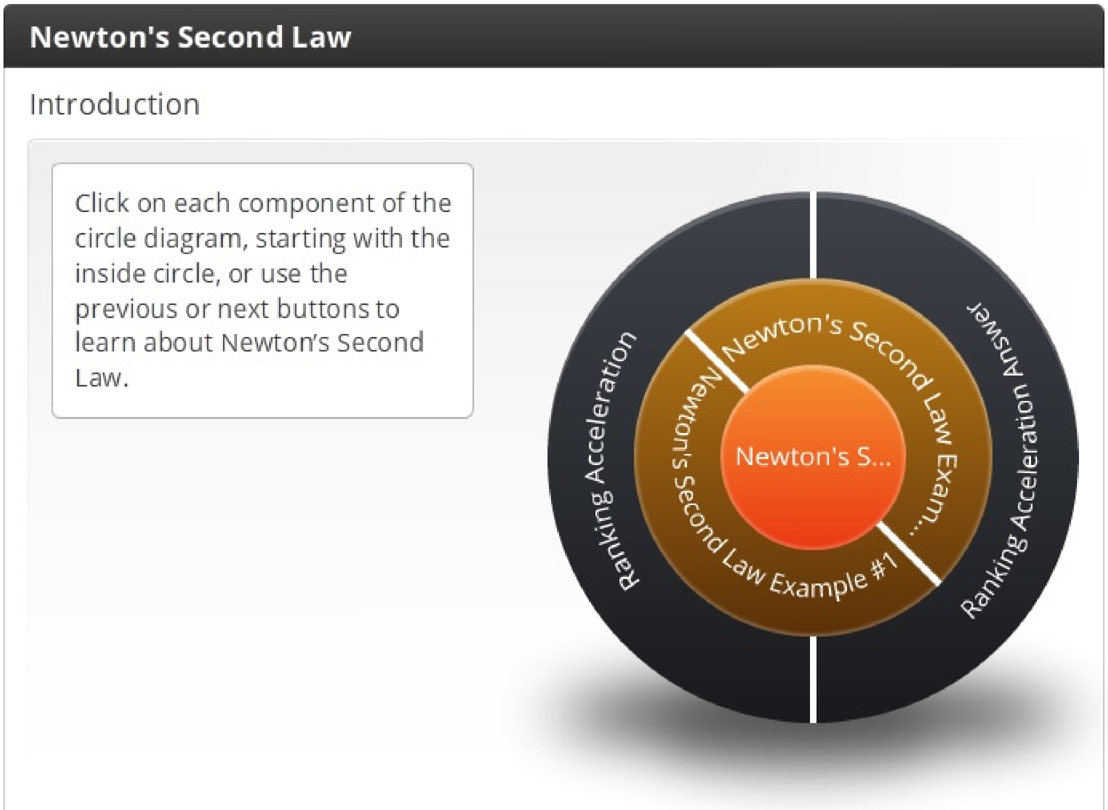
Module 2: Newton's Second Law and Unbalanced Forces
Topic 3 Content: Newton Second Law

Introduction



Click on each component of the circle diagram, starting with the inside circle, or use the previous or next buttons to learn about Newton's Second Law.

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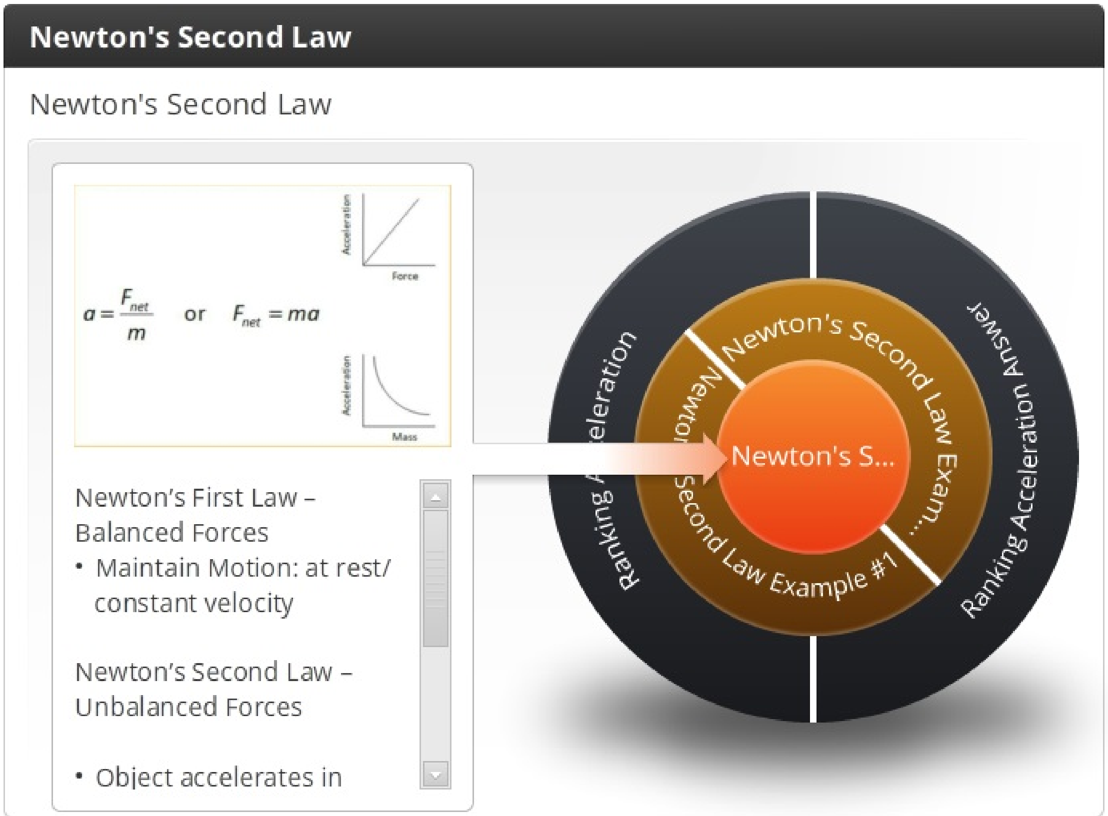
Newton's Second Law



Remember Newton's 1st and 2nd Law for balanced and unbalanced forces?

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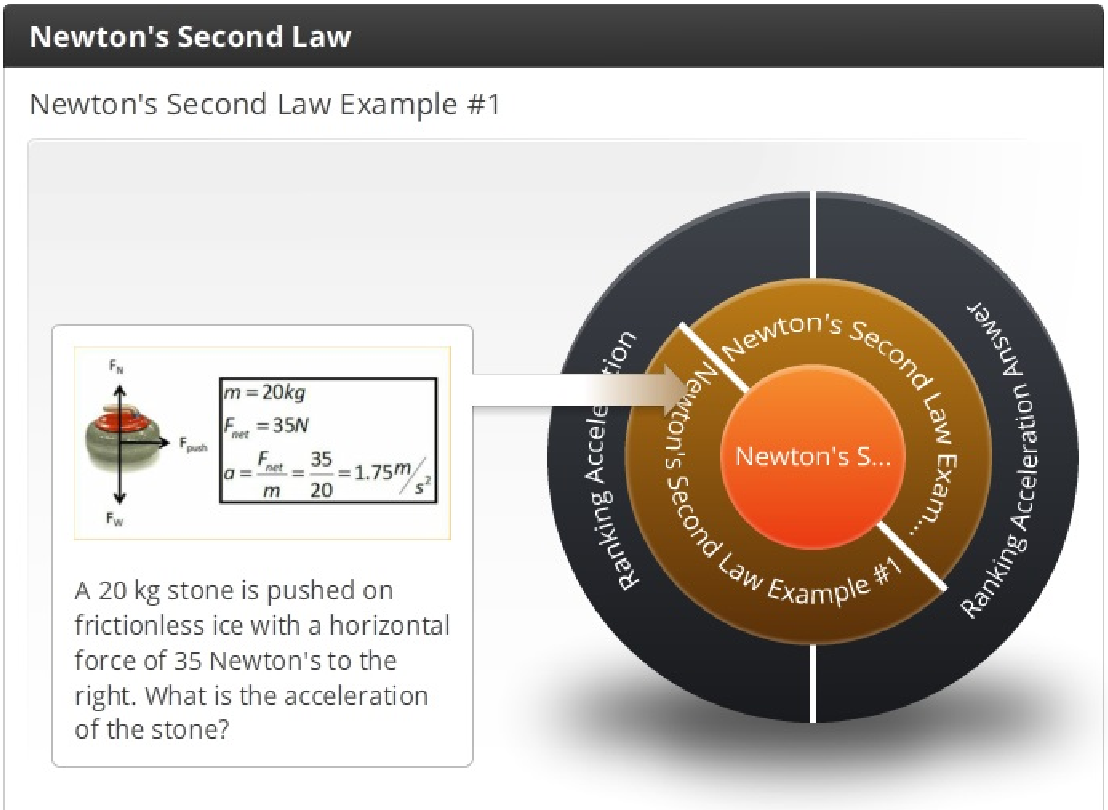
Newton's Second Law Example #1



First, it will be helpful to draw a free body diagram of the stone. We've got the gravitational force pulling down on the stone, the normal force from the ice pushing back perpendicular to the surface, and the push force of thirty five Newton's to the right.

We could calculate the gravitational force by multiplying the mass of the stone by the gravitational acceleration, but we can see that this force will be directly balanced by the normal force. Since these forces are balanced, they don't contribute to the net force on the stone.

Since there is no friction, the push force is going to be the net force acting on the stone. Now we should write down our variables, choose an equation and solve the problem.

The mass is twenty kilograms. The net force is thirty five Newton's. The equation we will use is *a* equals *F* net over *m*. As we substitute and solve, we see that the acceleration is one point seven five meters per second squared.

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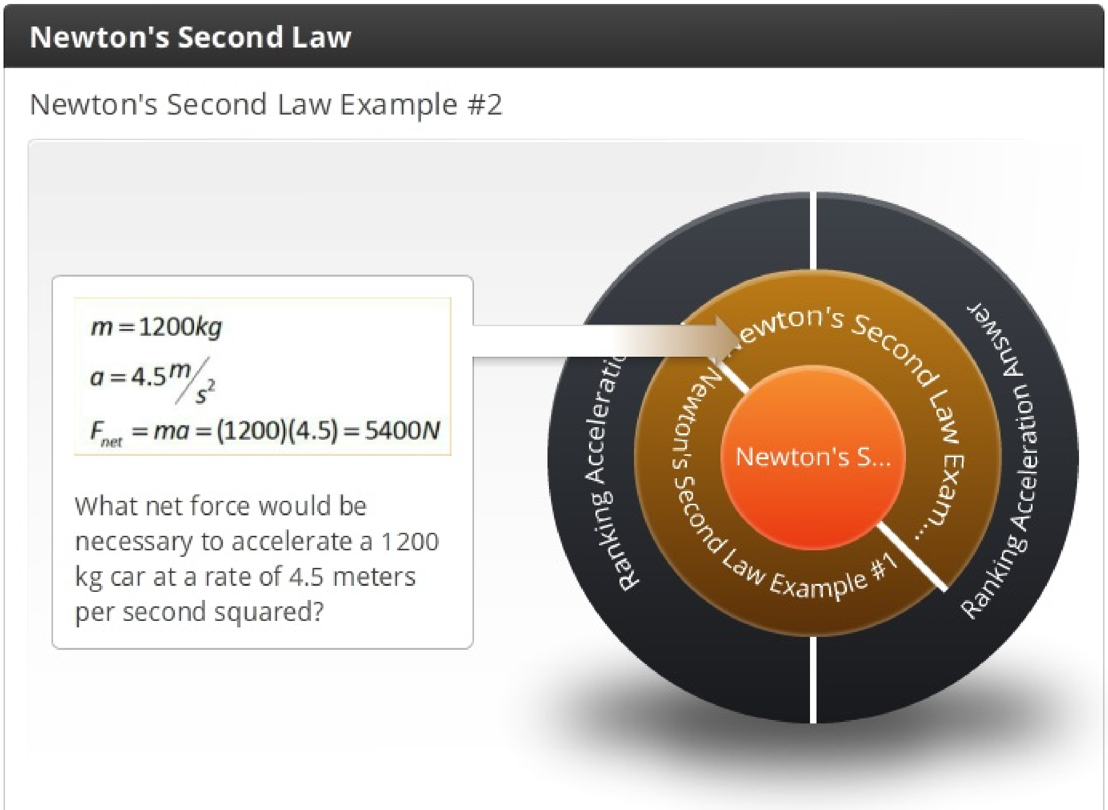
Newton's Second Law Example #2



Here's another example. What net force would be necessary to accelerate a twelve hundred kilogram car at a rate of four point five meters per second squared?

As we write down our variables, we see that m equals twelve hundred kilograms and a equals four point five meters per second squared. We will pick the second form of the equation for Newton's Second law, and write F net equals m a. Substituting and calculating shows that it would require a fifty four hundred Newton force.

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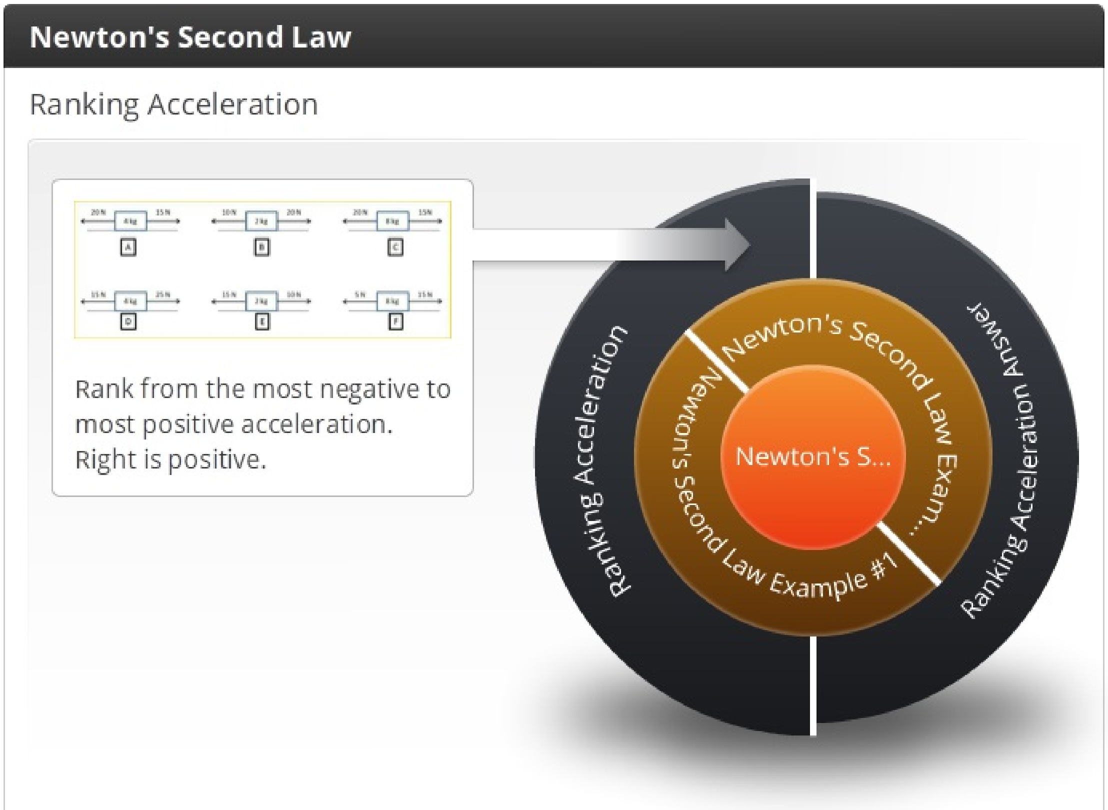
Ranking Acceleration



Each picture shows a mass on a frictionless surface subject to one or more forces. Rank the following situations in order from most negative acceleration to most positive.

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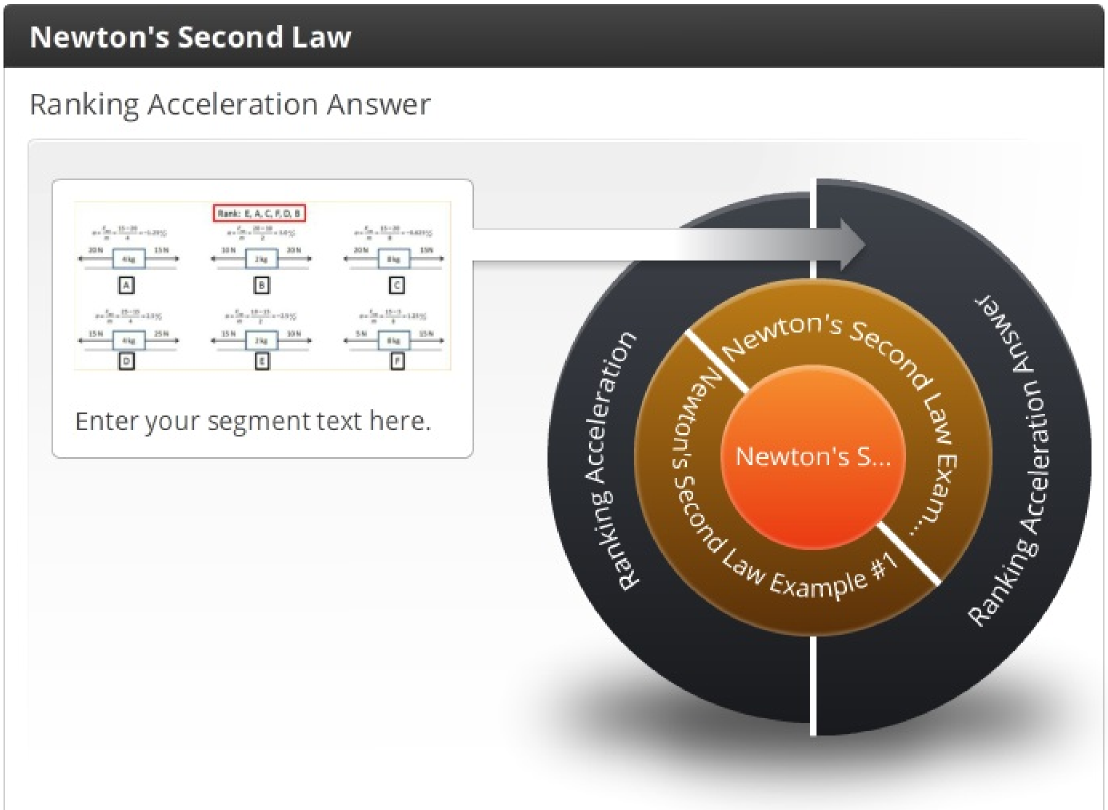
Ranking Acceleration Answer



The correct ranking is E, A, C, F, D, B. For each, you can first calculate the net force by subtracting the two horizontal forces. Then to calculate the acceleration, you divide the net force by the mass. You must pay attention to the sign of the acceleration because it tells you if it will be to the left, negative, or to the right, positive.

But what is particularly interesting here is to compare several of the scenarios. Scenarios B and D both have a net force of positive ten. But since the mass in scenario D is twice the mass in scenario B, the acceleration is half as much.

Scenarios A and D have the same mass, but the magnitude of the net force in A is half the magnitude of the net force in D, so the magnitude of the acceleration is half as much.

Comparing scenarios D and E, the magnitude of the force is twice as much in scenario D, but so is the mass, so the magnitudes of the acceleration turn out to be the same.

Similarly, comparing scenarios A and F, the magnitude of the net force on F is twice the magnitude of the net force on A, but so is the mass, so the magnitudes of the acceleration are the same.

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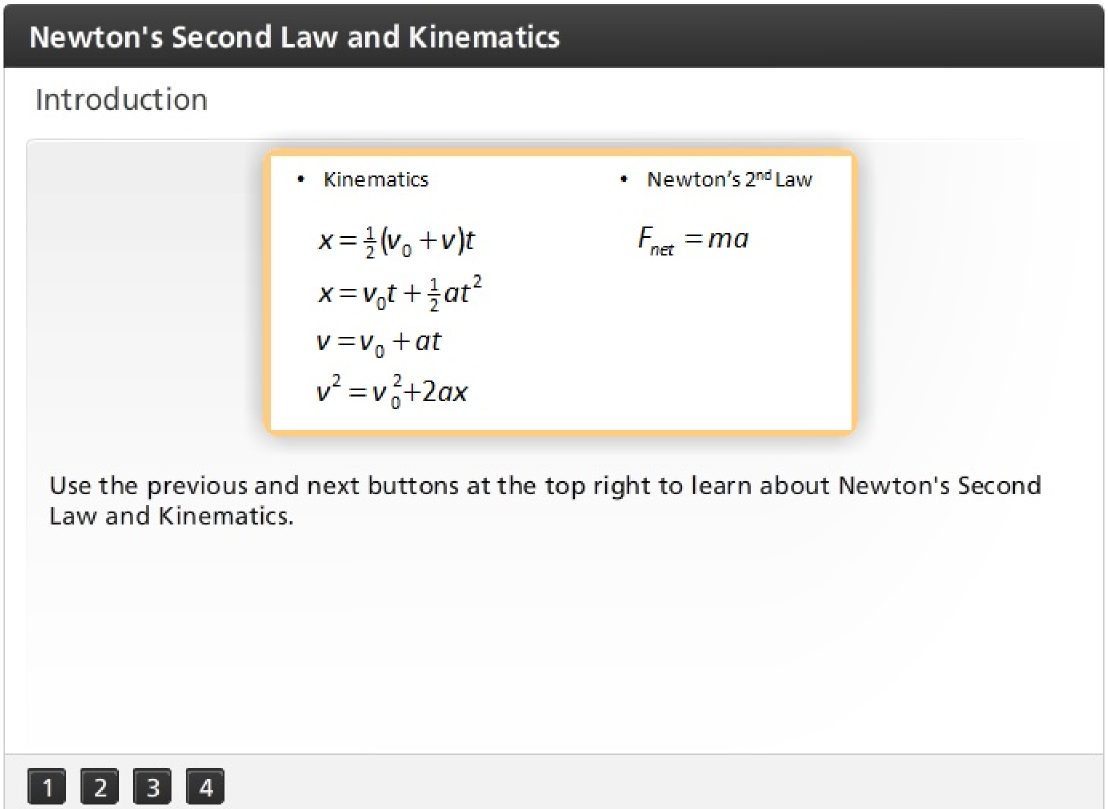

When we studied kinematics, we summarized our findings with four equations. These four equations tied together displacement, initial velocity, final velocity, acceleration and time. But they said nothing about masses or the forces acting on the object. Newton's second law shows the relationship between net force, the mass and the acceleration, but doesn't talk about velocity, displacement or time.

But both topics include acceleration, so we now have a broad range of questions we can answer as we combine our knowledge across these two topics.

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Example 1

Newton's Second Law and Kinematics

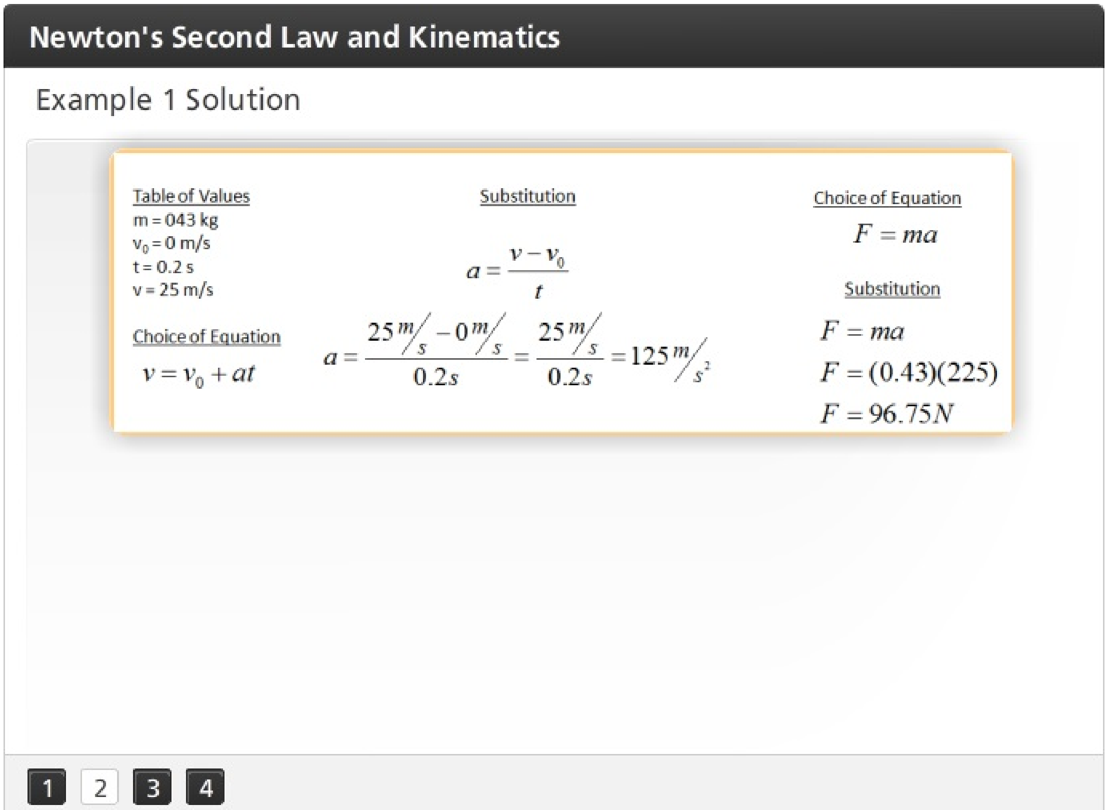
Example 1

A soccer player kicks a 0.43 kg ball initially at rest. Her foot is in contact with the ball for 0.20 s. and the ball leaves her foot with a speed of 25 m/s. What was the average force of her foot on the ball?

1 2 3 4

For example, a soccer player kicks a zero point four three kilogram soccer ball initially at rest. Her foot is in contact with the ball for zero point two seconds, and the ball leaves her foot with a speed of twenty five meters per second. What was the average force of her foot on the ball?

Example 1 Solution



It will be useful to first create our table of values. We see that the mass of the ball is zero point four three kilograms. The initial velocity of the ball is zero. The time of contact is zero point two seconds and the final velocity is twenty five meters per second.

This problem is looking for the force on the ball. We could try to solve for this using F equals m a, but we don't yet know the acceleration, so we'll have to use our kinematics equations to solve for acceleration first. Given that we have initial velocity, final velocity and time, we can use the equation v equals v zero plus a t. As we rearrange, substitute and solve, we find that the acceleration is one hundred twenty five meters per second squared.

Now that we have acceleration, we can calculate the average force, knowing mass and acceleration. For this we will choose the equation F equals m a. When we substitute and solve, we find that the force on the ball must be ninety six point seven five Newtons.

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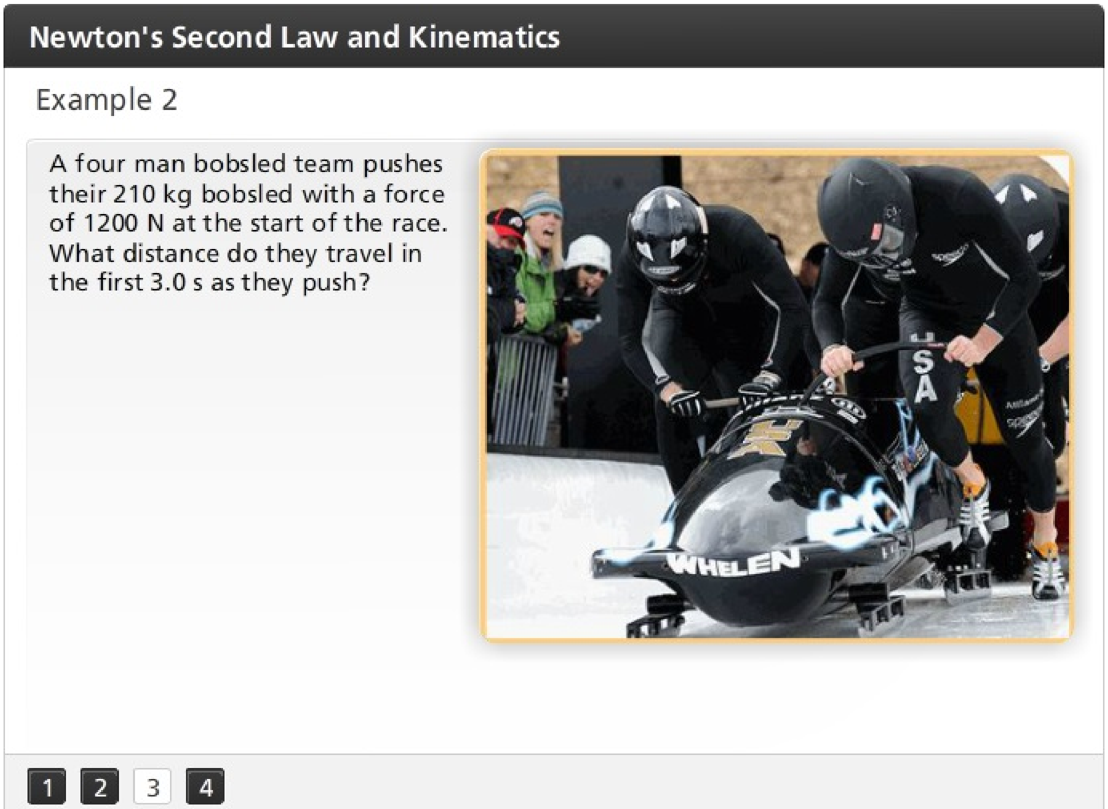
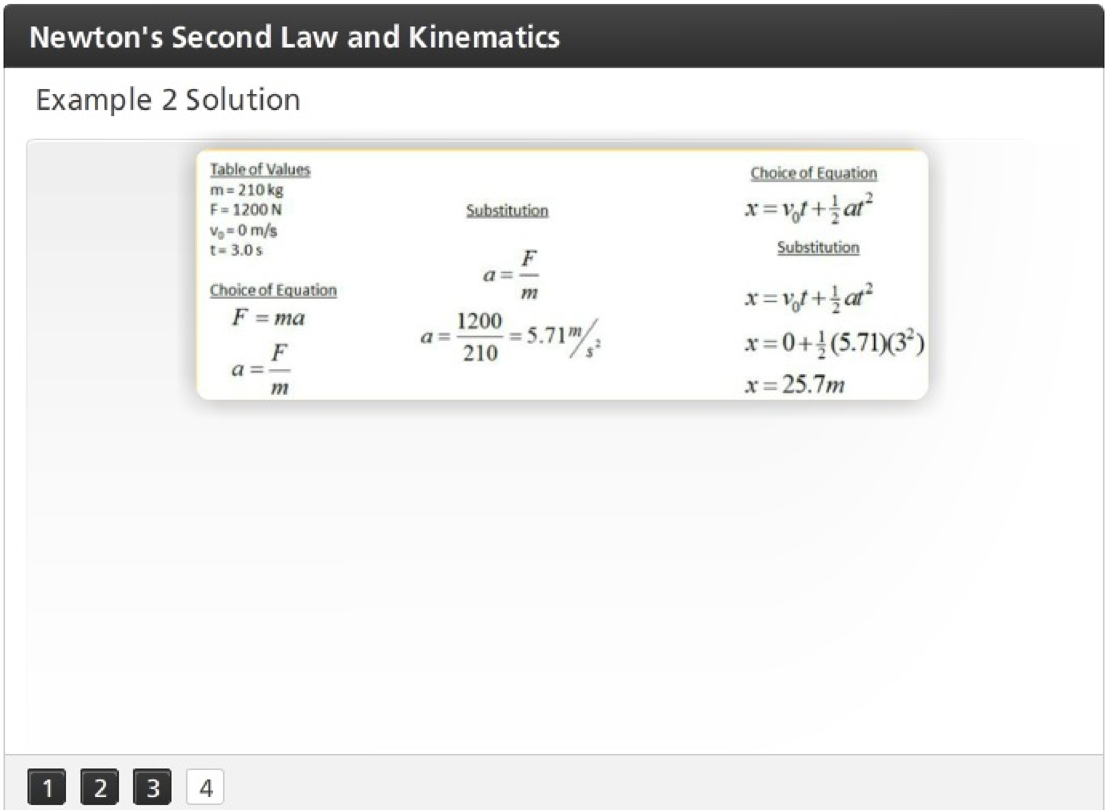
Example 2



As our second example, we'll consider the start of a Bobsled race. The four man team applies a force of 1200 Newton's to the two hundred ten kilogram bobsled at the start of the race. What distance do they travel in the first three point zero seconds of pushing?

Example 2 Solution



Again, we should start with a table of values. The mass of the sled is two hundred ten kilograms. The force on the sled is twelve hundred Newton's. The initial speed of the sled is zero meters per second, and the time of the push is three point zero seconds.

In this case, we could solve for the displacement if we also knew the acceleration, so we should use Newton's second law first to calculate acceleration.

When we substitute the force and mass into Newton's second law, we see that the acceleration is five point seven meters per second.

Now that we know the acceleration, we can use our kinematics equations to solve for the displacement. The equation *x* equals *v* zero *t* plus one half a *t* squared has the variables we need to solve for displacement.

When we substitute and solve, we find that the displacement is twenty five point seven meters.