The Car Push Lab

A large-scale application of Newton's Laws involves pushing automobiles with bathroom scales. The objective of the car push laboratory is to determine the mass of a vehicle based on the acceleration produced by a net force.

After obtaining parental and administrative permission, two or three students are asked to bring their cars to school for use in the car push lab. In addition to the cars, laboratory equipment includes three household bathroom scales, a stopwatch, measuring tape, and eight to ten safety cones.

Three students are selected to push the car with the bathroom scales. The sum of the three scale readings provides the value of the force applied to the car. With stopwatch in hand, a student in the back seat of the car says "go" and the driver releases the brake. Every two seconds thereafter, the timer says "drop." With each order to drop, a student in the passenger's seat places a safety cone onto the pavement through an open door. The markers provide a record of the position of the car as a function of time. The students' reaction to the increasing distance between the cones alone makes the experiment worth doing!

Safety cones being dropped during acceleration phase of experiment.

Students measure and record the distance between cones using the measuring tape. The frictional force acting on the car is found by determining the applied force needed to keep the car moving at a constant velocity. This is done with a single bathroom scale. Since the car must be in equilibrium if it's moving with constant velocity, Newton's 1st Law implies that the applied force must just equal to the frictional force.

After all cars are pushed, twice if time permits, students return to the classroom to analyze data. The average velocity of a car between each pair of cones is calculated by dividing the measured distances between cones by two seconds. From the slope of each car's average velocity versus time graph, students determine acceleration. The net force is found by subtracting the frictional force from the force applied by three bathroom scales.

Finally, the mass is found by applying Newton's 2nd Law: m =F/a where m is the mass, F is the net force, and a is the acceleration. The experimentally determined mass is then compared with the mass of the car found in the owner's manual or online.

Some observations and suggestions:

1) Safety is of paramount importance! It goes without saying that drivers of the vehicles should drive responsibly. Once the car is positioned for a push, the engine should be turned off, car placed in neutral and brake applied.

2) Have students place foam rubber or other soft material between the bathroom scales and the car body to prevent scratching.

3) An applied force of 30 to 50 pounds per scale (total applied force of 90 to 150 pounds) usually works well.

4) Make certain students push horizontally. If they push at an angle, only the horizontal component of the applied force goes into accelerating the car. As a result, the actual applied force will be less than the scale reading.

5) Have one student monitor the scale readings during acceleration. This is accomplished by having the student run behind the three "pushers" to keep them honest. As you might imagine, it's quite difficult to keep the scale reading constant as the car accelerates.

6) The person placing the cones on the pavement should wear a seatbelt to prevent falling. This person should be told to place the cones firmly on the pavement. Because of Newton's 1st law, the cones tend to keep moving along with the car: a nice lesson but a hindrance to good data.

7) To determine the mass of the car in kilograms, distances between cones must be measured in meters and forces in newtons. To convert pounds to newtons, multiply the force in pounds by 4.45 N/pound.