SCIENCE NORTH SCIENCE NORD
SUDBURY, ONTARIO, CANADA

Balloon Car Races and Breaking Newton's 3rd Law — Grade 11 – Forces

Lesson Plan

Assessment	AOL (Balloon Car Activity)
Cross-curricular	

Big Ideas

- Forces can change the motion of an object.

Learning Goals

- I can use appropriate terminology related to forces, including: mass, time, speed, velocity, acceleration, friction, gravity, normal force, and free-body diagrams.
- I can use free-body diagrams as well as appropriate equations to analyse motion.
- I can state Newton's 3rd Law and apply it to explain the effect of forces acting on objects.

Specific Expectations:

B2. investigate, in qualitative and quantitative terms, uniform and non-uniform linear motion, and solve related problems;
B2.1 use appropriate terminology related to kinematics, including, but not limited to: time, distance, position, displacement, speed, velocity, and acceleration
B2.7 solve problems involving uniform and non-uniform linear motion in one and two dimensions, using graphical analysis and algebraic equations
C1. analyse and propose improvements to technologies that apply concepts related to dynamics and Newton's laws, and assess the technologies' social and environmental impact;
C1.1 analyse, with reference to Newton's laws, a technology that applies these laws, and propose ways to improve its performance
C2. investigate, in qualitative and quantitative terms, net force, acceleration, and mass, and solve related problems;
C2.1 use appropriate terminology related to forces, including, but not limited to: mass, time, speed, velocity, acceleration, friction, gravity, normal force, and free-body diagrams
C2.5 plan and conduct an inquiry to analyse the effect of forces acting on objects in one dimension, using vector diagrams, free-body diagrams, and Newton's laws
C3. demonstrate an understanding of the relationship between changes in velocity and unbalanced forces in one dimension.
C3.3 state Newton's laws, and apply them, in qualitative terms, to explain the effect of forces acting on objects

Description:

In this lesson, students will build and race balloon cars. They will use free-body diagrams and appropriate equations to analyse motion in the context of Newton's 3rd Law of motion. **This lesson is intended for the university level.**

Materials

Balloon Car Race Activity (Student)
Balloon Car Race Activity Group Materials**:**

- Lego, cardboard, or other materials, make sure you have wheels
- Balloons all the same type, from the teacher
- Piece of string 80 cm long
- Bent straw

NASA Success at Testing EMDrive which may lead to Warp Drive! video
Provides Lasting Propulsion and High Speeds for Deep Space Missions video
Balloon Car Analysis Rubric

Safety Notes

There are no safety issues in this lesson plan.

Introduction

Begin this lesson with the Balloon Car Race Activity. Students should be given class time (approximately 20 minutes) before the race day to design their car together and plan to scavenge any building materials they may require.

The students may race the cars all at once, or each car may be timed separately. An app like Video Physics would allow the students to videotape their vehicle and it will graph both position and velocity. From the velocity graph, students can identify their initial velocity, for use in further calculations. There should also be a scale available to students for the measurement of the car's mass. Students should learn Newton's Three Laws before race day, as this activity is a demonstration of Newton's Third Law.

In groups of 3-4, students will create a small car (maximum dimensions = 30 cm long and 20 cm wide) with a space on the back to secure the mouth of a balloon. Students will be racing their car against other teams in the class for both the shortest time to cross the finish line, and the total distance it travels, so students will make sure their car is designed with these goals in mind. Students should sketch a labelled drawing of their car design, and make a list of materials along with who will procure them. "Upcycling" or reusing materials is encouraged.

Action

Balloon Car Race Activity

Group Materials:

- Lego, cardboard, or other materials, make sure you have wheels

- Balloons all the same type, from the teacher
- Piece of string 80 cm long
- Bent straw

Instructions:

1. Build your car and include an area at the back where the mouth of a balloon could be secured. This may be a hole in a piece of cardboard, big enough to get the straw into the mouth of the balloon.
2. All balloons should be of the same type and should be blown up to the same circumference before racing. The string should be used to measure and control the circumference.
3. Test your balloon racing car and make adjustments. Indicate any major changes on your original drawing.

Now, students will all race their cars. Two people should blow up the balloon, check the circumference, and hold the car at the starting line.

One person should time the car or use the Video Physics app on an Ipad or other tablet to videotape and graph the trajectory. There may be up to three winning cars – the fastest, the furthest, and the most stylish. Now, with your team, you will analyze your car's motion.

Balloon Car Analysis

A. Create a free-body diagram of your car as it is in motion.
B. Using the displacement of your car and a measurement or estimate of the initial velocity, calculate its acceleration using the equation(s) for uniform acceleration.
C. Use the graphing information from the Video Physics App to calculate the acceleration again.
D. Compare these two numbers. Does this acceleration seem reasonable? What sources of error may have been introduced into your experimental measurements?
E. Now, using Newton's Second Law, calculate the force of friction acting on the car.
F. Which of Newton's Laws is at play in the car's motion? Describe how this law applies to the movement of the car.

Submit your car design, revisions, and analysis to your teacher for assessment (See Link).

Consolidation/Extension

The balloon cars move due to an application of Newton's Third Law which states, "for every action force, there is an equal and opposite reaction force". As the air blown into the balloon escapes out the back, the balloon pushes on the air (the action force), and the air pushes back on the balloon (reaction force), propelling the car forward. This is similar to rocket thrust in space where the action force (produced by combustion, a chemical reaction) of exhaust pushing forward on the rocket and being expelled backward into space is equal and opposite to the reaction force of the rocket pushing backward on the exhaust and propelling forward in the opposite direction.

The EMDrive is an electromagnetic thruster, which violates Newton's Third Law: it seems to develop thrust from nowhere. Watch this video to see why scientists and science-fiction enthusiasts are so excited!

NASA Success at Testing EMDrive which may lead to Warp Drive!
https://www.youtube.com/watch?v=YVxqejyQUfM

The EmDrive uses a high-powered vacuum tube wherein microwaves are generated through the interaction of a magnetic field and electrons. It then sends the microwaves into a cone of a specific shape, creating resonance, and where they hit the short end of the cone and generate thrust. The thrust is thus "generated" from inside the system, which should be impossible according to laws of momentum (for example, what would happen if you tried to pull yourself up by your own shoelaces?). While the amount of force generated is minute, further research could lead to rockets, which do not require fuel – enabling interstellar travel!

In 2015, both a NASA-based group and a group from Germany attempted to replicate this drive in experiments and claim to have detected minute amounts of thrust (30-50 micronewtons and 20 micronewtons respectively) that are unexplained by any sources of error or other sources. However, both experiments did not conclude that the thrust was necessarily caused by the EMDrive, but rather, could be caused by other unexplained reasons such as quantum fluctuations.

NASA has however, been working on Ion Propulsion engines that use the emission of charged particles to propel a spacecraft. NEXT, NASA's Evolutionary Xenon Thruster has been tested for over 48,000 hours and has used only 860 kg of xenon as propellant, this is less than $1/10^{th}$ the fuel that would be used by a conventional rocket for the same momentum. Ion propulsion may enable further space travel as a rocket could carry much less fuel.

NEXT Provides Lasting Propulsion and High Speeds for Deep Space Missions
http://www.nasa.gov/content/next-provides-lasting-propulsion-and-high-speeds-for-deep-space-missions