Hungary – ÉSZC Százhalombattai Széchenyi István Szakgimnáziuma és Gimnáziuma	
Subject: Physics	**Topic:** Newton’s Second Law

Objectives:

- Students are introduced to Newton's second law of motion: force = mass x acceleration
- After a review of force, types of forces and Newton's first law, Newton's second law of motion is presented.
- Both the mathematical equation and physical examples are discussed, including Atwood's Machine to illustrate the principle. Students come to understand that an object's acceleration depends on its mass and the strength of the unbalanced force acting upon it.
- Students learn the use of Newton's second law in real life (e.g. used by engineers while designing machines, structures, products such as towers, bridges, bicycles or cribs)
- Students carry out an experiment and make calculations

1. **In groups of four students revise their knowledge of forces by answering three questions:**
    - What is a force?
    - What are the 2 categories of forces?
    - What are 7 kinds of forces we have learned so far?

Answers:

Definition of a force: A push, pull or twist of an object.

2 categories: contact forces and non-contact forces.

Contact forces: interactions between objects that touch
Non-contact forces: attract or repel, even from a distance

7 types of forces:

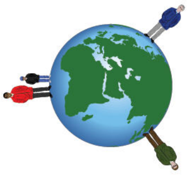
Contact forces: applied, spring, drag, friction
Non-contact-forces: magnetic, electric, gravitational

2. **Teacher shows pictures and asks students to try and identify the types of forces depicted.**

Contact force: applied force

Contact forces: applied forces and friction

Contact force: drag, non-contact force: force of gravity



Contact force: the normal force, non-contact force: the force of gravity

Non-contact force: magnetic force

Non-contact force: electric force

3. Students review Newton's First Law by answering questions:

- What is the scientific unit of forces? (Answer: Newton)

- What is Newton's First Law of Motion? (Answer: Newton's First Law states that an object will remain at rest or in uniform motion in a straight line unless acted upon by an external force.)

- Give examples of this law: if you slide a hockey puck on ice, eventually it will stop because of friction on the ice. It will also stop if it hits something, eg. a goalpost or a player's stick.

- What is acceleration? (Answer: it is a change in velocity. Applying a force can change an object's velocity.)

4. **Teacher presents Newton's second law by a simple experiment. Students are encouraged to discuss experiences in groups of four.**

Experiment:
First, teacher constructs a simple ramp on a smooth floor using a thin piece of plywood and some books. Then places a toy car at the top of the ramp and releases it. The toy car rolls down the ramp and also moves some distance before it stops. Teacher marks the distance that the toy car has moved on the floor.
Second, teacher tapes one coin to the top of the car, then places the car on the top of the ramp and releases it. Students will notice how far the car moves now. To continue experimenting teacher tapes two more coins to the top of the car and measure how far it travels.
Students' conclusion: as more coins are added, the farther the car moves. This shows that when the mass of the toy car increases, the gravity that acts on the toy car increases and thus the distance the toy car moves on the floor also increases.

5. **Newton's second law is formulated:**

Newton's second law of motion states that the acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

Mass is the amount of matter an object contains.

Weight is a gravitational force; a measure of how strongly gravity pulls on an object.

Your weight depends on the strength of gravity:

$F = m \times a$
Force= $m \times g$

On Earth, the ***force*** due to ***gravity*** is medium-sized; on the moon, it is tiny; on Jupiter, it is really huge. Notice that the ***force changes*** as does the ***acceleration due to gravity*** on each planet; it depends on each planet's mass and radius (squared). The mass is like Goldilocks, it does not change size, only the surroundings or the environment changes.

6. **To check their understanding teacher encourages students to complete these sentences using words.**

1. Newton's second law can be written mathematically as:

   _____________ = _____________ x _____________.

2. From Newton's second law, an object's acceleration depends on the object's _______ and the strength of the ___________ _____ acting on it.

3. Your _____________ will be different on other planets because the acceleration due to gravity is different.

4. BONUS: What are some examples of engineering designs that must consider Newton's second law of motion?

Answers:

1. Newton's second law can be written mathematically as: ***force = mass x acceleration***

2. From Newton's second law, an object's acceleration depends on the object's ***mass*** and the strength of the ***unbalanced force*** acting on it.

3. Your ***weight*** will be different on other planets because the acceleration due to gravity is different.

4. *The design of vehicles, structures and products.*

7. **Tasks for students with simple calculations and a little thinking. The first few are done together with the help of the teacher, others are done in class and some may be assigned as homework.**

- A satellite in deep space is on a mission to Neptune. It fires its engines to change its velocity toward Neptune at a speed of 200 kilometers per hour. Suddenly, the engines stop working. After a few minutes, what is the velocity of the satellite?

A. 100 kilometers per hour, towards Neptune

B. 200 kilometers per hour, towards Earth

C. 100 kilometers per hour, towards Earth

D. 200 kilometers per hour, towards Neptune

Answer: The answer is D. The velocity of the satellite is the same as before, since (almost) no unbalanced forces are acting upon the satellite in outer space. (That is, no air resistance and almost no gravitational forces exist to act to change the trajectory of the satellite.)

- An 80 kg skier has a force of 200 N exerted on him down the slope.
  - Calculate his acceleration down the slope.
  - Is the slope less than or more than 45°? Explain your answer.

- An ice hockey player has a sudden impact force of 2000 N exerted on him due to unexpected collision with the wall. The mass of the player is 100 kg.
  - Find his acceleration.
  - Compare this with the acceleration when he free falls.

- Coming out of a dive, 75 kg astronauts in training experience an acceleration of 40 ms–2.
  - Calculate the force acting on them.
  - Compare this with the force which normally acts on them when stationary on Earth.
  - Why is it important that they are seated and strapped in before the dive ends?

- A 50 g tennis ball may be accelerated at 1000 m s–2 to reach a service speed of 130 mph.
  - Calculate the force required to accelerate the ball.
  - Is your answer reasonable? Comment.

- When a force of 200 N is exerted on an asteroid it accelerates at 0.002 m s–2.
  - Find the mass of the asteroid.

Answers and worked solutions:

1.

$$a = \frac{F}{m} = \frac{200\ \text{N}}{80\ \text{kg}} = 2.5\,\text{m}\,\text{s}^{-2}$$

2. Slope is less than 45° because at this angle, force down slope = weight / √2, which is greater than 200 N.

3.

$$a = \frac{2000\ \text{N}}{100\ \text{kg}} = 20\,\text{m}\,\text{s}^{-2}$$

4. Twice
5. 3000 N
6. Four times
7. Astronauts will be brought to rest at the end of the dive which may require the application of a large force resulting in injury.
8. $F = ma = 0.050\ \text{kg} \times 1000\ \text{m s}^{-2} = 50\ \text{N}$
9. Not very large – as you can probably lift 250 N with one arm.
10.

$$m = \frac{200\ \text{N}}{0.002\,\text{m}\,\text{s}^{-2}} = 1.0 \times 10^{5}\ \text{kg}$$