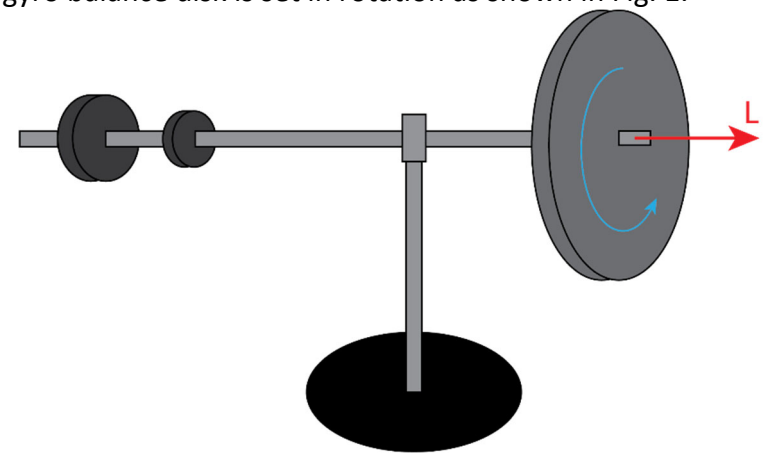
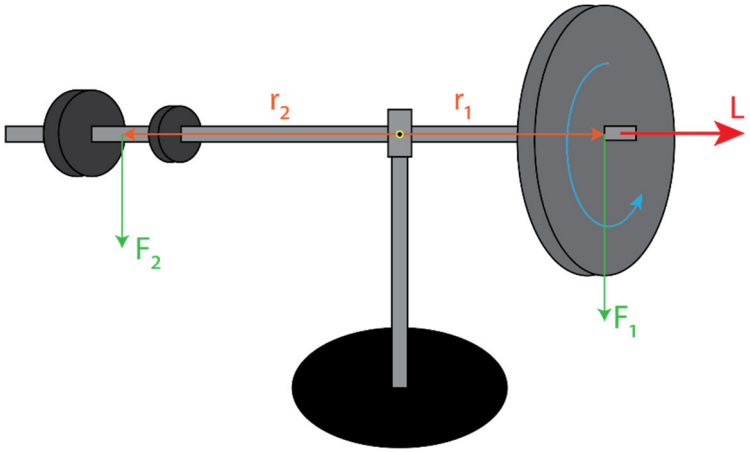
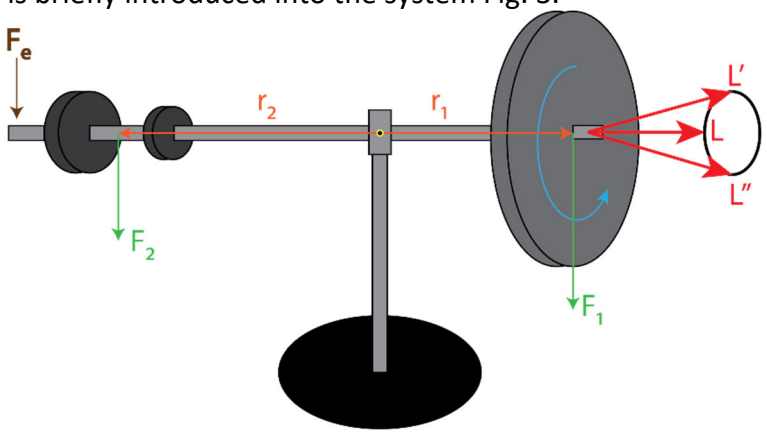
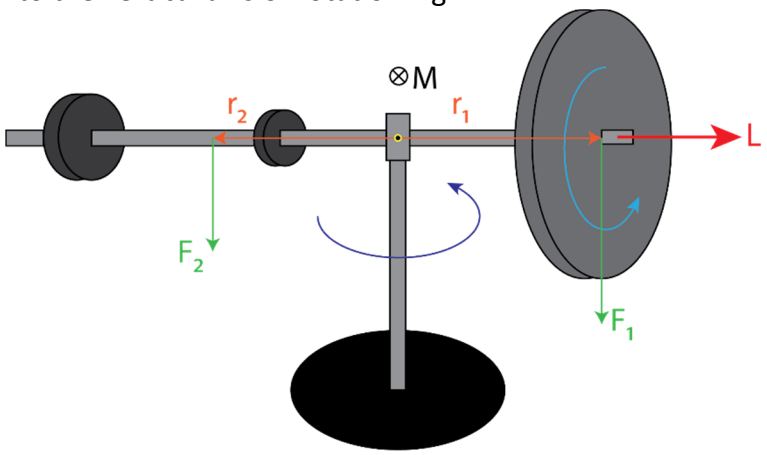
The scenario

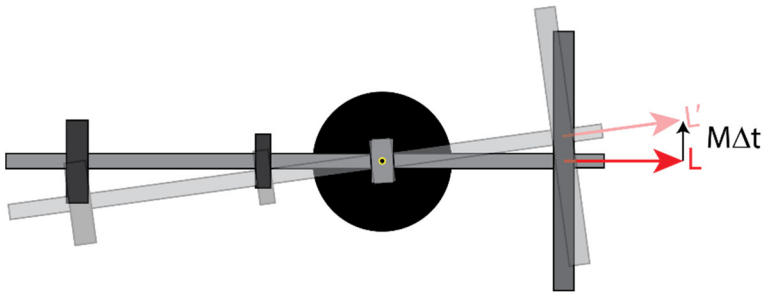
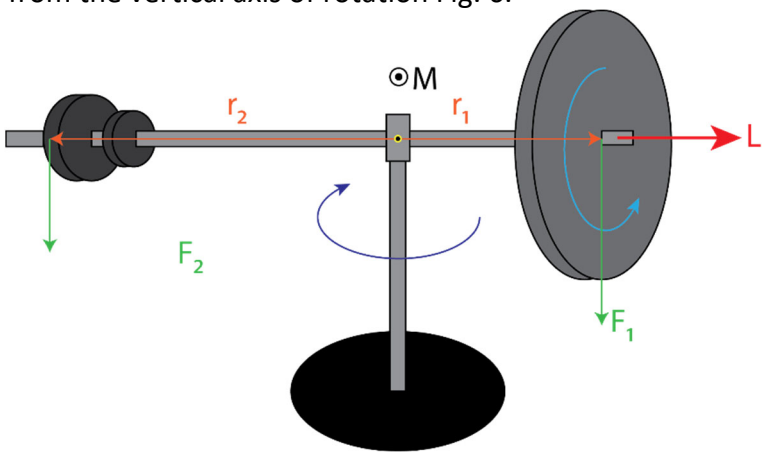
Topic	Mechanics, Gyroscope
Movie length	4:43
Main Objectives	Rigid body dynamics
Specific goal	Explanation of precession and nutation.
Structure and description of the experiments:	
1. Introduction	Observation of the behaviour of the gyro balance when the weight distribution on its arms changes.
2. Main topic	The aim of the experiment is to introduce students to topics related to the concept of precession and nutation. Presentation of the phenomenon of precession and nutation, discussion of the moment of force.
Part 1	
Experiment 1: 1:20	***Materials*** *:* • *gyro scale,* • *weights,* • *string.* **Description** : The gyro balance disk is set in rotation as shown in Fig. 1.  Fig. 1. Initial position of the gyro scale. We turn the scale and watch what happens. We see that the axis of rotation keeps time in one direction all the time. The balance does not spin about the vertical axis. **Questions** : Why doesn't the scale spin around the vertical axis of rotation? What can we say about power coins? Where in everyday life do we deal with balancing moments of forces? **Conclusions:**

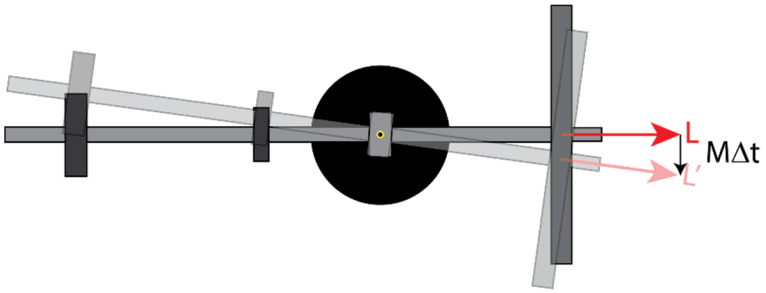
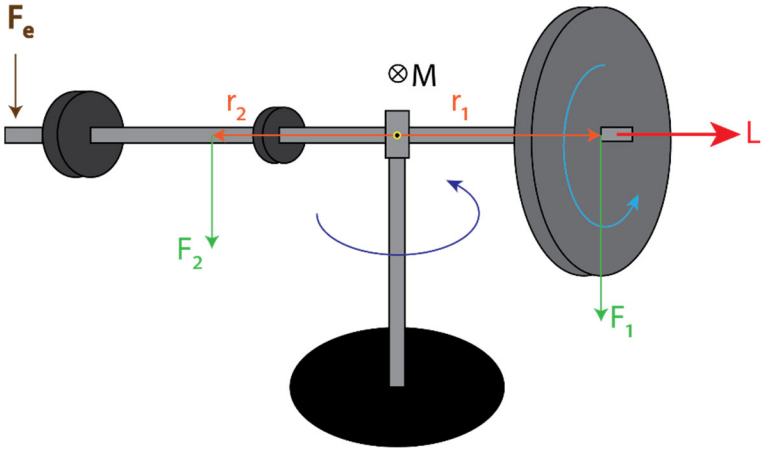
Co-funded by the Erasmus+ Programme of the European Union

	When the masses are distributed on the balance in such a way that the moments of force balances out, there are no external contributions to the system and angular momentum is conserved. The scale remains in balance, does not spin about the vertical axis of rotation.  Fig. 2. Distribution of forces - balance in balance. $r_2 > r_1$ $m_2 < m_1$ $\vec{r}_1 \times F_1 = \vec{r}_2 \times F_2$ $\vec{M}_1 = \vec{M}_2$
Experiment 2: 1:40	***Materials*** *:* • *gyro scale,* • *weights,* • *string.* **Description** : The gyro balance disk remains spin as before. An external unbalanced force is briefly introduced into the system Fig. 3.  Fig. 3. Changing the direction of the angular momentum vector. We turn the balance around the vertical axis and observe what happens. We see that the axis of rotation keeps one direction all the time, but there is an additional movement of it.

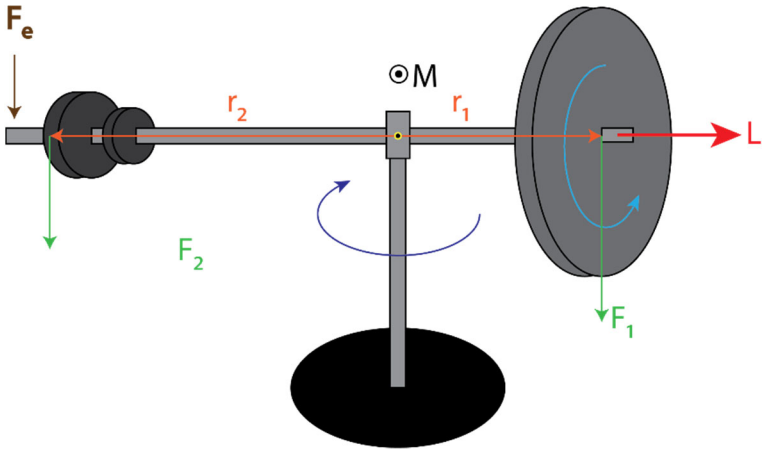
	Questions : Why did the extra movement appear in the system? Where in everyday life do we face a similar situation? How long is the Earth's nutation period? What causes Earth nutation? Are there also nutations for a spinning top (toy)? Does the force of gravity from the moon and sun affect the nutation of the earth? **Conclusions:** The introduction of a short-term external force into the system causes nutation.
Experiment 3: 2:06	***Materials*** *:* • *gyro scale,* • *weights,* • *string.* **Description** : The gyro balance disk remains spin as before. We change the distribution of the mass on the left side. We move a small weight closer to the vertical axis of rotation Fig. 4.  Fig. 4. Distribution of forces for a gyro balance. After moving the weight to the right, the balance begins to spin with a spinning disc towards the experimenter. **Questions** : Why did the extra movement appear in the system? Where in everyday life do we face a similar situation? How long is the Earth's precession period? What is causing the Earth's precession? Is there precession for a spinning top (toy) too?

Co-funded by the Erasmus+ Programme of the European Union

	Conclusions: Analysing the situation in Fig. 4, we can present the system as follows: Fig. 5.  Fig. 5. View from above for the situation in Fig. 4. As a result of the appearance of an unbalanced moment of force in the system, the balance begins to rotate - the angular momentum vector changes its direction.
Experiment 4: 2:38	***Materials*** *:* • *gyro scale,* • *weights,* • *string.* **Description** : The gyro balance disk remains spin as before. We change the distribution of the mass on the left side. Move the small weight farther away from the vertical axis of rotation Fig. 6.  Fig. 6. Distribution of forces for a gyro balance. After moving the weight to the left, the balance begins to rotate with a spinning disc from the experimenter. **Questions** : as above **Conclusions:**

	Analysing the situation in Fig. 6, we can present the system as follows: Fig. 7.  Fig. 7. View from above for the situation in Fig. 6. As a result of the appearance of an unbalanced moment of force in the system, the balance begins to rotate - the angular momentum vector changes its direction.
Experiment 5: 3:13	***Materials*** *:* • *gyro scale,* • *weights,* • *string.* **Description** : The gyro balance disk remains spin as before. We change the distribution of the mass on the left side. We move a small weight closer to the vertical axis of rotation and apply an external force as in Fig. 8.  Fig. 8. Distribution of forces for a gyro balance. After moving the weight to the right, the balance begins to spin with a spinning disc towards the experimenter. In addition, nutation is visible (Experiment 3). **Conclusions:** The system is a combination of two experiments and allows to present the full motion of the gyroscope (top) taking into account external forces. The experiment can be related to the precession of the Earth with nutation.

Co-funded by the Erasmus+ Programme of the European Union

Experiment 6: 3:40	***Materials*** *:* • *gyro scale,* • *weights,* • *string.* **Description** : The gyro balance disk remains spin as before. We change the distribution of the mass on the left side. We move a small weight further from the vertical axis of rotation and apply an external force as in Fig. 9.  Fig. 9. Distribution of forces for a gyro balance. After moving the weight to the left, the balance begins to rotate with a spinning disc from the experimenter. In addition, nutation is visible (Experiment 3). **Conclusions:** As in experiment 5.
Summary, evaluation and comments	**Application:** The film can be used at the beginning of the lesson as an introduction to issues related to mechanics and astronomy, and as a summary to test students' knowledge. It deals with the subject of angular momentum, torque, unbalanced forces in the system. **Level:** secondary school

Co-funded by the Erasmus+ Programme of the European Union