Kicking Life into Classroom

Demonstrator # 12

Pirouettes, pirouettes - the study of angular momentum, moment of inertia

TEACHER NOTES

Activity title:

Kicking life into Classroom: Pirouettes, pirouettes - the study of angular momentum, moment of inertia

Subject:

Physics - Class IX

Student age:

14-16 years

Estimated duration:

2x50 minutes (50 minutes, for data collecting, 50 minutes for data processing)

Science content

- Angular momentum
- angular momentum variation theorem
- Moment of Inertia
- InLOT System

Learning objectives

Lesson is valuable because creatively exploit knowledge like angular momentum, moment of inertia, practical skills through non-formal learning contexts applicability, such as sport.

SPECIFIC COMPETENCIES: At the end of this lesson students will be able to:

- to apply the law of angular momentum, moment of inertia and to strengthen their understanding
- to understand dependencies between different physical quantities specific for solid body circular motion by mathematical modelling of this process
- to capitalize the knowledge of geometry
- to use creatively INLOT system in applied contexts
- to explore the physical reality testing AM handy devices in solid body circular motion

Inquiry-based character

The student will enhance their work skills specific scientific investigation and discovery activities geared for this type of learning:

1. Identify Questions for Scientific Investigations

- Identify testable questions
- Refine/refocus ill-defined questions
- Formulate hypotheses

2 Design Scientific Investigations

- Design investigations to test a hypothesis
- Identify independent variables, dependent variables, and variables that need to be controlled
- Operationally define variables based on observable characteristics
- Identify flaws in investigative design
- Utilize safe procedures
- Conduct multiple trials

3 Use Tools and Techniques to Gather Data

- Gather data by using appropriate tools and techniques
- Measure using standardized units of measure
- Compare, group, and/or order objects by characteristics
- Construct and/or use classification systems
- Use consistency and precision in data collection
- Describe an object in relation to another object (e.g., its position, motion, direction, symmetry, spatial arrangement, or shape)

4 Analyze and Describe Data

- Differentiate explanation from description
- Construct and use graphical representations
- Identify patterns and relationships of variables in data
- Use mathematic skills to analyze and/or interpret data

5 Explain Results and Draw Conclusions

- Differentiate observation from inference
- Propose an explanation based on observation
- Use evidence to make inferences and/or predict trends
- Form a logical explanation about the cause-and-effect relationships in data from an experiment

6 Recognize Alternative Explanations and Predictions

- Consider alternate explanations
- Identify faulty reasoning not supported by data

7 Communicate Scientific Procedures and Explanations

- Communicate experimental and/or research methods and procedures
- Use evidence and observations to explain and communicate results
- Communicate knowledge gained from an investigation orally and through written reports,
  incorporating drawings, diagrams, or graphs where appropriate

Applied technology (if any)

In order to do so the KLiC project uses an innovative sensor data collection tool, namely the InLOT system (www.inlot.eu) that consists of the following modules:

• ***SensVest*** - a vest, equipped with various sensors, designed to carry components that measure and transmit physiological data to the base station.
• ***Leg and Arm Accelerometer*** - small devices attached to the leg and/or arm that enable the

3-D measurement of the acceleration for the leg and/or arm.
Ball Accelerometer - a ball that has embedded an accelerometer measuring three dimensions and a communication unit that enables the transmission of data packets to the base.
• ***Base Station*** - responsible for the collection of all transmitted data
• ***User Interface Software*** - user friendly interface, designed with a pedagogical frame of mind, that enables the process of data and actions such as plotting data on a graph or creating a mathematical model to fit the data.

User details can be found in Annex 7.1.

Materials needed

- InLOT system
- PC
- natural kit: mechanical oscillations
- worksheet (Annexes 7.1, 7.2 and 7.3)

Discussion guide

Anticipation: Unit summary: Angular momentum. Variation of the angular momentum theorem, moment of inertia.

Essential Question: *How physics helps us to better understand the sorrounding world?*

Before a project approach

Before using a project approach, the high school students will review the principles of Newtonian dynamics, will discuss techniques for working with INLOT system, then write an essay about the use of physical knowledge in sports. Essays will be between three and five pages and will be noted. Essays will be evaluated in terms of Newtonian dynamics harnessing knowledge about techniques for working with INLOT system discussed above.

After a project approach

After the scenario proposed sequence no.7 has been completed, indicated that students apply the theme and new skills to the situations described by their essays. Students will be invited to explore the questions: a) *How physics helps us to better understand the surrounding world?* and *b) How that gives us the performance perspective?*. Students will analyze how science and technology in performance are mutually supportive and not just athletes

Building knowledge
Teaching strategy

- The teacher monitors and advises business groups, provides support points, support students in their approach.
- Use project method
- Integrate knowledge and skills achieved an adequate framework for reflection.

Reflection / Consolidation
Evaluation method: gallery tour

Assessment

- ✓ summative
- ✓ formative

Annex 7.1

Using **accelerometer**

Photo accelerometer

Reference directions of accelerometer

What accelerometer (AM) measures?

- The frames of reference in which the experiments are conducted are non-inertial, so it is necessary to simplify the model; therefore we encourage the selection of appropriate experimental contexts secondary level approach.
- It appears that AM measures, momentary, relative acceleration in non-inertial frames of reference. Generally, according to kinematics in non-inertial frames of reference:

$$\vec{a}_{rel} = \vec{a}_{abs} - (\vec{a}_{cor} + \vec{a}_{transp}) \qquad (0.1.)$$

$$m \cdot \vec{a}_{rel} = m \cdot \vec{a}_{abs} - m \cdot (\vec{a}_{cor} + \vec{a}_{transp}) \qquad (0.2.)$$

$$m \cdot \vec{a}_{rel} = \vec{F} + \vec{F}_c \qquad (0.3.)$$ [1]

-Accelerometer (AM) measures the difference between the momentary gravitational component (reference direction Ox of AM), plus centrifugal momentary acceleration (if a change of direction of motion) and momentary acceleration of movement of AM in that direction.

$$a_x = g_x + a_{cfx} - a_{mx} \qquad (0.4.)$$

Where: - a_x is the value measured on test direction (relative acceleration)

- g_x is the component of gravity acceleration on test direction

---

1. where $\vec{F}_c$ is supplementary forces.

Particularly, there are situations (eg, a ball suspended at rest relative to the earth, but relative to a man sitting on a rotating wheel, the ball appears to be in rotation), where it may happen that the body viewed from S does not any force, but still to see him moving accelerated relative to S' due to supplementary force, $\vec{F}_c$:

$$a_{abs} = 0 \Rightarrow \vec{F} = 0 \rightarrow \vec{F}_c = m \cdot \vec{a}_{rel} \qquad (0.5.)$$

An important class of reference frames is the object's own frame or frame-related rigid object moving uniformly force from their frame (eg the man and the object (= S') are resting on the rotating disc, and the object is caught in a spring). In such frames the object is evident in the rest ($\vec{a}_{rel} = 0$), although there is a real force $\vec{F}$. In this case: $\vec{F} + \vec{F}_c = 0 \rightarrow \vec{F}_c = m \cdot \vec{a}_{rel}$. That supplementary force is equal but opposite to the real force, so it is equivalent to the Newtonian inertial force.

Supplementary forces are fictitious forces that should be added to the real forces to ensure the validity of the IInd principle of newtonian mechanics in non-inertial frames. These are not forces of interaction, we can show the body that produces them, so it does'nt applies the IIIrd principle of newtonian mechanics.

- a_{cfx} is the component of centrifugal acceleration on test direction
- a_{mx} is the acceleration of movement (accelerometer and body together) on test direction (acceleration of transport).

$$a_y = g_y + a_{cfy} - a_{my} \quad (0.6.)$$

$$a_z = g_z + a_{cfz} - a_{mz} \quad (0.7.)$$

If the motion is made on certain direction, relatively to the reference directions of AM, then the previous relations are wrote on each component of the acceleration measured by accelerometer (≠0).

All measured values are fractions of g (gravity acceleration), expressed relative to the value of g for which was calibrated AM.

Cases:

I. $a_{mx} = 0$ (AM is at rest, set on the object whose motion is studied, or in rectilinear and uniform motion on test axis, chosen as the Ox axis)

$$\Rightarrow a_x = g_x + a_{cfx} \quad (0.8.)$$

- More if $a_{cfx} = 0$

$$\Rightarrow a_x = g_x \quad (0.9.)$$

II. $g_x = 0$ (the test axis is in a perpendicular plane on vertical)

$$\Rightarrow a_x = a_{cfx} - a_{mx}. \quad (0.10.)$$

- In addition if $a_{cfx} = 0$

$$\Rightarrow a_x = -a_{mx} \quad (0.11.)$$

This is the method of determining the acceleration of motion of AM/the object bounded on AM.

What we can measure with the accelerometer in the laboratory / practical applications?

- *Angles*: AM in resting, sat alongside a surface makes an angle α with the vertical;

$$a_x = g \cdot \sin\alpha \Rightarrow \alpha = \arcsin\frac{a_x}{g} \quad (0.12.)$$

- Acceleration of translational motion on:
    - Axis in the horizontal plane regardless of the gravity component
    - Axis of the other plane, but taking into account the gravity component
- Acceleration of complex motion (rotation and translation)

Annex 7.2

ASSESSMENT TOOLS

Scores for project evaluation

1 = Criterion is not fulfilled	3 = Criterion is fulfilled in good measure
2 = Criterion is met only slightly	4 = The criterion is fully met

1. All team members undertake collaborative activities by completing the steps in processing aid given to them and collect data for one of the roles within the team

   1 2 3 4

2. Each member fulfills the role it has in the team. Team members' work together to achieve a quality presentation

   1 2 3 4

3. Presentation made meet the recommended structure.

   1 2 3 4

4. Explanation contained in the presentation is enlightening to the public

   1 2 3 4

5. Project presentation is eloquent and enlightening for the audience participating.

   1 2 3 4

6. The manner of presentation is attractive and involving public

   1 2 3 4

7. Team members are open to public questions and formulate answers all questions pertinent to public

   1 2 3 4

8. Introducing the team roles demonstrates that members are knowledgeable in all fields covered by the project.

   1 2 3 4

9. Team members speak out loud, communicates a very clear presentation of content, and establish eye contact with audience.

   1 2 3 4

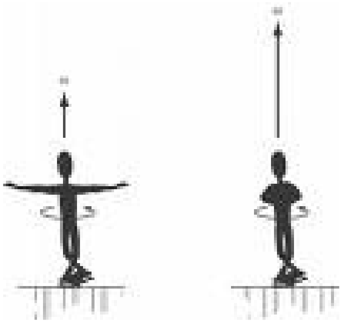
10. Team members provide additional explanations to the public request, using the flip chart

    1 2 3 4

Completion:
Note: The lesson is built valuing prior knowledge acquired in different learning contexts and integrates communication skills, collaboration skills, investigation, practical skills, but also interpersonal and social skills, artistic skills and expression.

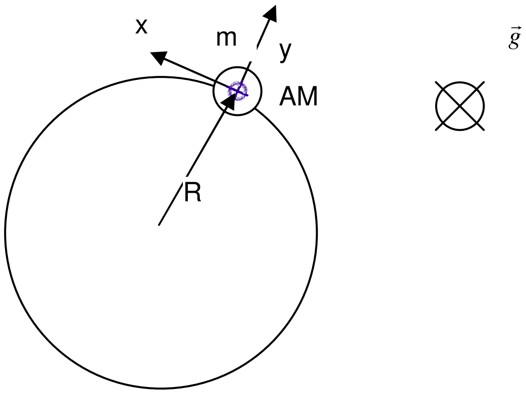
Annex 7.3
AUXILIARY FOR TEACHING

Kicking life into Classroom: Pirouettes, pirouettes - the study of angular momentum, moment of inertia



Not once have been bewitched by the beauty of figure skating. Art and science also ...
We now enter into the secrets of a perfect pirouette, which arouse public admiration. The magic of art skaters will be deciphered in the physics lab with our partner AM and InLOT system.
Once we entered the secret will be left only to practice ...
Good luck!

7.II. Into Lab with InLOT: the study of angular momentum, moment of inertia

Modeling physical phenomena: The conservation of the angular momentum	**Principle method**
7.II.A. The angular momentum **7.II.A.1. The case of material point in uniform circular motion** Consider a material point of mass m that is rotating uniformly around a vertical axis (perpendicular to the paper), whose direction does not vary over time. [i].  fig.7.1. Illustration of circular and uniform body of mass m (AM) in the horizontal plane and the Ox axis direction indicated by the AM. **The momentum of material point** in uniform circular motion around its fixed axis is given by the expression: p = m · v, 7.1. where v is the speed module of uniform circular motion, v = constant. We therefore infer that in uniform circular motion and the module of the momentum of the	**Conservation of angular momentum and to highlight the relationship between rotation velocity and the moment of inertia** We arrived at the situation described in Part I, skater (with fixed AM A1 to hand) make pirouettes, experiment in which we use InLOT highlight system based on conservation of angular momentum, relation between angular velocity of rotation and moment of inertia. Here, only it should be noted that, since the uniform circular motion when external force is zero, under variation of the angular momentum theorem, that the rate of change of angular momentum is zero and so while the angular momentum is conserved (remains constant). Therefore any change in moment of inertia related to a change in mass distribution relative to the axis of rotation causes a change in angular velocity, so, $L = I_1 \cdot \omega_1 = I_2 \cdot \omega_2 = const.$ 7.11. **7.II.A. Calculating the angular velocity** $a_y = \omega^2 R$ 7.12 $\omega = \sqrt{\dfrac{a_y}{R}}$ 7.13 is the angular velocity of the uniform circular motion (see scenario no. 6). **7.II.B. The conservation of the angular**

material point is constant.
Pulse point size material is therefore expressing its state of motion and depends on its mass and velocity. Also momentum is a vector and speed as having the same direction and with the same sense of speed.

$$\vec{p} = m \cdot \vec{v} \qquad 7.2.$$

Angular momentum is defined as the time pulse vector size, expressed as:

$$\vec{L} = \vec{r} \times \vec{p} \qquad 7.3.$$

Angular momentum vector direction is perpendicular to the plane formed by vectors $\vec{r}$ and $\vec{p}$. In the laboratory reference system experiment is carried out in a horizontal plane (see gravitational acceleration vector direction oriented perpendicular to the paper and drop down in the lab SR). Meaning of the angular momentum vector is indicated below, to the viewer, perpendicular to the paper, and the lab SR is oriented vertically upwards.

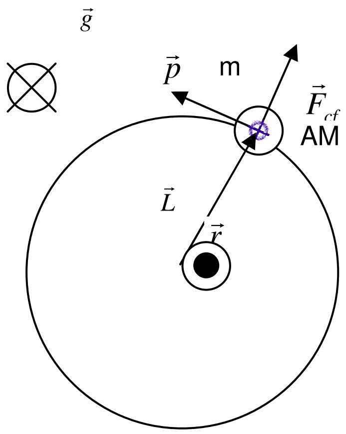


fig. 7.2. Illustration of momentum and angular momentum vectors in uniform circular motion AM, in a horizontal plane and the direction indicated by the vector momentum

7.II.A.2. The case of the rigid body was in uniform circular motion

Define a rigid body as a material point for which the distance between any pair of points is always seamless.

Resume the previous discussion in the body meaning rigidly defined above all sizes are assigned to the rigid body this time. We believe, therefore, a rigid body which rotates uniformly about an axis whose direction does not vary over time. Any material point i, with the mass m_i, located at

momentum

Returning to equation (7.11), highlight the conservation of angular momentum as:

$$I_1 \cdot \omega_1 = I_2 \cdot \omega_2 . \qquad 7.14.$$

$$I_2 = I_1 \cdot \frac{\omega_1}{\omega_2} \qquad 7.15.$$

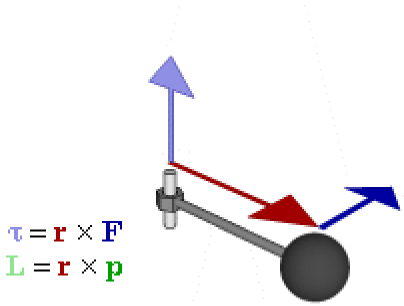
If $\frac{\omega_1}{\omega_2} > 1$ then $I_2 > I_1$, i.e. with increasing of I, decreases velocity, rotation is slower.

But how can I grow? By moving part of the rigid body mass on the axis of rotation. For example, skater hands away, I grow and angular velocity decreases.

Than, if $\frac{\omega_1}{\omega_2} < 1$ than $I_1 > I_2$, i.e. with decreasing of I, increases velocity, rotation is faster.

Referring to the same skater example, the moment of inertia, I, decreases when approaching skater hand, as showed in figure 7.1. and the angular velocity increases.

These observations can be confirmed by experimental measurements.
Checking equation 7.15. will be subject to experimental determinations.



a distance r_i from the axis of rotation, moves by a circle of radius ri, located in a plane perpendicular to the direction of rotation, with speed v_i oriented on the direction tangent to the circle you, like in fig. 7.2 .
The angular momentum:

$$\vec{L}_i = \vec{r}_i \times \vec{p}_i = m_i \vec{r}_i \times \vec{v}_i \qquad 7.4.$$

of the material point with the mass m_i as part as the solid body leads to total angular momentum:

$$\vec{L} = \sum_{i=1}^{N} \vec{L}_i = \sum_{i=1}^{N} \vec{r}_i \times \vec{p}_i = \sum_{i=1}^{N} m_i \vec{r}_i \times \vec{v}_i \qquad 7.5.$$

Since all points move as circles material contained in the same plane or in planes parallel, all individual angular momentum $\vec{L}_i$, have the same direction, follows that the module of the total angular momentum is expressed as the algebraic sum of the modules of the individual angular momentum.

$$L = \sum_{i=1}^{N} L_i = \sum_{i=1}^{N} r_i p_i = \sum_{i=1}^{N} m_i r_i v_i \qquad 7.6.$$

here we consider that $L_i = m_i r_i v_i$, and the vectors $\vec{r}_i$, $\vec{v}_i$ are mutually perpendicular.

Given that the angular velocity is the same for all points; it can be taken outside the summation sign. Replacing $v_i = \omega \cdot r_i$ follows:

$$L = \omega \sum_{i=1}^{N} m_i r_i^2 \qquad 7.7.$$

7.II.B. The moment of inertia

From 7.7. a simple definition of the **moment of inertia** is given by:

$$I = \sum_{i=1}^{N} m_i r_i^2 \qquad 7.8.$$

The mathematical relation between angular momentum and the momentum of inertia is given by:

$$L = I \cdot \omega \qquad 7.9.$$

and more generally,

$$\vec{L} = I \cdot \vec{\omega} \qquad 7.10.$$

STUDENT WORKSHEET

Activity title:

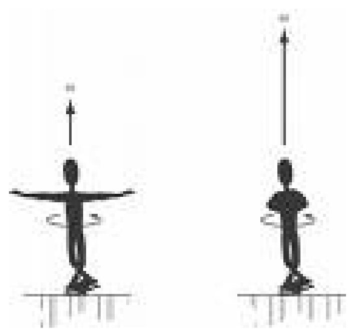
Kicking life into Classroom: Pirouettes, pirouettes - the study of angular momentum, moment of inertia

Introduction

Curriculum-Framing Questions
Essential Question
How would the universe appear without regular phenomena?
Unit Questions.
At what extent the laws of mechanics which are already known can be applied to periodic phenomena?
What immediate applications do you see for the study of periodic phenomena in nature?
Questions of content
What periodical mechanical phenomena can we identify in the nature? What physical quantities are characteristic for the oscillatory movement? How can we represent harmonic oscillator motion laws? What happens to energy in motion harmonic oscillator? Under the action of which type of force a harmonic oscillatory motion is present? What is the difference between the damped oscillation and the ideal one.

Thinking about the question

Kicking life into Classroom: Pirouettes, pirouettes - the study of angular momentum, moment of inertia



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7.II. Into Lab with InLOT: the study of angular momentum, moment of inertia

Modeling physical phenomena: The conservation of the angular momentum	Principle method

7.II.A. The angular momentum

7.II.A.1. The case of material point in uniform circular motion

Consider a material point of mass m that is rotating uniformly around a vertical axis (perpendicular to the paper), whose direction does not vary over time. [ii].

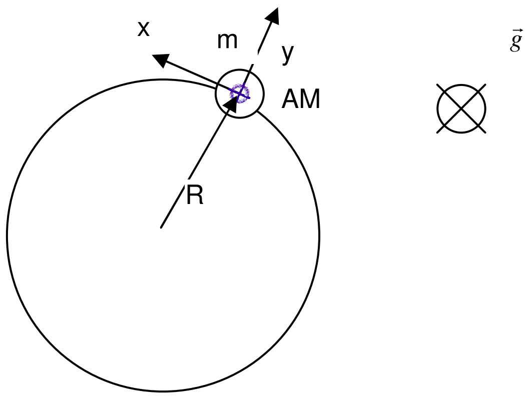

fig.7.1. Illustration of circular and uniform body of mass m (AM) in the horizontal plane and the Ox axis direction indicated by the AM.

The momentum of material point in uniform circular motion around its fixed axis is given by the expression:

$$p = m \cdot v, \qquad 7.1.$$

where v is the speed module of uniform circular motion, v = constant.
We therefore infer that in uniform circular motion and the module of the momentum of the material point is constant.
Pulse point size material is therefore expressing its state of motion and depends on its mass and velocity. Also momentum is a vector and speed as having the same direction and with the same sense of speed.

$$\vec{p} = m \cdot \vec{v} \qquad 7.2.$$

Angular momentum is defined as the time pulse vector size, expressed as:

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We arrived at the situation described in Part I, skater (with fixed AM A1 to hand) make pirouettes, experiment in which we use InLOT highlight system based on conservation of angular momentum, relation between angular velocity of rotation and moment of inertia.
Here, only it should be noted that, since the uniform circular motion when external force is zero, under variation of the angular momentum theorem, that the rate of change of angular momentum is zero and so while the angular momentum is conserved (remains constant). Therefore any change in moment of inertia related to a change in mass distribution relative to the axis of rotation causes a change in angular velocity, so,

$$L = I_1 \cdot \omega_1 = I_2 \cdot \omega_2 = const. \qquad 7.11.$$

7.II.A. Calculating the angular velocity

$$a_y = \omega^2 R \qquad 7.12$$

$$\omega = \sqrt{\frac{a_y}{R}} \qquad 7.13$$

is the angular velocity of the uniform circular motion (see scenario no. 6).

7.II.B. The conservation of the angular momentum

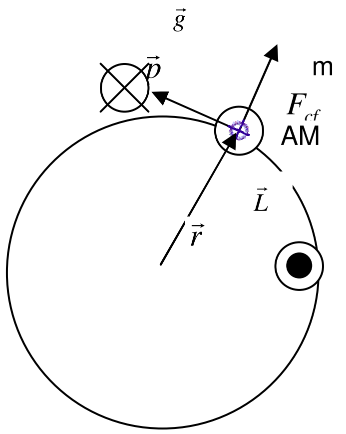
Returning to equation (7.11), highlight the conservation of angular momentum as:

$$I_1 \cdot \omega_1 = I_2 \cdot \omega_2 . \qquad 7.14.$$

$$I_2 = I_1 \cdot \frac{\omega_1}{\omega_2} \qquad 7.15.$$

If $\frac{\omega_1}{\omega_2} > 1$ then $I_2 > I_1$, i.e. with increasing of I, decreases velocity, rotation is slower.

But how can I grow? By moving part of the experiment is carried out in a horizontal plane (see gravitational acceleration vector direction oriented perpendicular to the paper and drop down in the lab SR). Meaning of the angular momentum vector is indicated below, to the viewer, perpendicular to the paper, and the lab SR is oriented vertically upwards.



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Define a rigid body as a material point for which the distance between any pair of points is always seamless.
Resume the previous discussion in the body meaning rigidly defined above all sizes are assigned to the rigid body this time.
We believe, therefore, a rigid body which rotates uniformly about an axis whose direction does not vary over time. Any material point i, with the mass m_i, located at a distance r_i from the axis of rotation, moves by a circle of radius ri, located in a plane perpendicular to the direction of rotation, with speed v_i oriented on the direction tangent to the circle you, like in fig. 7.2 .
The angular momentum:

$$\vec{L}_i = \vec{r}_i \times \vec{p}_i = m_i \vec{r}_i \times \vec{v}_i \qquad 7.4.$$

of the material point with the mass m_i as part as the solid body leads to total angular momentum:

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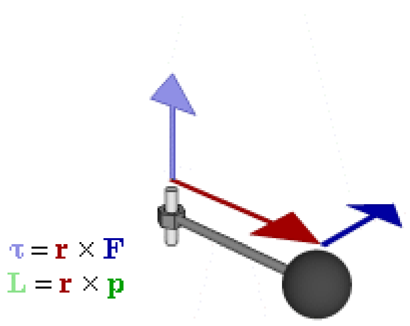

$$\vec{L}=\sum_{i=1}^{N}\vec{L}_i=\sum_{i=1}^{N}\vec{r}_i\times\vec{p}_i=\sum_{i=1}^{N}m_i\vec{r}_i\times\vec{v}_i \qquad 7.5.$$ Since all points move as circles material contained in the same plane or in planes parallel, all individual angular momentum $\vec{L}_i$, have the same direction, follows that the module of the total angular momentum is expressed as the algebraic sum of the modules of the individual angular momentum. $$L=\sum_{i=1}^{N}L_i=\sum_{i=1}^{N}r_i p_i=\sum_{i=1}^{N}m_i r_i v_i \qquad 7.6.$$ here we consider that $L_i=m_i r_i v_i$, and the vectors $\vec{r}_i$, $\vec{v}_i$ are mutually perpendicular. Given that the angular velocity is the same for all points; it can be taken outside the summation sign. Replacing $v_i = \omega{\cdot}r_i$ follows: $$L=\omega\sum_{i=1}^{N}m_i r_i^{2} \qquad 7.7.$$ **7.II.B. The moment of inertia** From 7.7. a simple definition of the **moment of inertia** is given by: $$I=\sum_{i=1}^{N}m_i r_i^{2} \qquad 7.8.$$ The mathematical relation between angular momentum and the momentum of inertia is given by: $$L=I\cdot\omega \qquad 7.9.$$ and more generally, $$\vec{L}=I\cdot\vec{\omega} \qquad 7.10.$$	

Materials needed

- **InLOT system**
- **PC**
- **kit physics:** rigid solid study
- Worksheet

Safety

Follow the rules of labour protection in the physics laboratory.

Investigation

Name and surname of the participants: 1.____________,2.____________, 3. _______________, 4.____________, 5. ___________
Category ☐ student; ☐ teacher; ☐ athlete; ☐ other
Age: ___________, gender: ☐ M, ☐ F

<table>
<tr><th>Experimental determinations</th><th>Action plan:</th></tr>
<tr>
<td>
a. without weightlifting
7.II.A. Calculating angular velocity

The size of a_{y1} measured by accelerometer is:
a_{y1} = ________ m/s²

The distance between sternum and AM in position 1:
R_1 = __________ m

The size of the angular velocity ω_1 is:
ω_1 = ___________ rad/s

The size of a_{y2} measured by accelerometer is:
a_{y2} = ________ m/s²

The distance between sternum and AM in position 2:
R_2 = __________ m

The size of the angular velocity ω_2 is:
ω_2 = ___________ rad/s

7.II.B. Calculating ratio $\frac{\omega_1}{\omega_2}$

The size of ratio $\frac{\omega_1}{\omega_2}$ is:
$\frac{\omega_1}{\omega_2}$ = _________

Discussion conclusions concerning the relationship between sizes I_1 şi I_2, in the two positions and interpretation the results:
</td>
<td>
Use InLOT platform for collecting data:

7.II.A. Calculating the angular velocity
1. A1 accelerometer is mounted hand sleeve skaters ready to perform rotations around a vertical axis, as shown 7.1.
2. Determine first a_{y1}, then ω_1 using equation 7.13, position with hands apart, measuring R_1, as distance between sternum and AM, in the position on the wrist of hand.
3. Determine, than, a_{y2}, than ω_2 using equation 7.13, position with hands near sternum, measuring R_2, as distance between sternum and AM, in the position on the wrist of hand.

7.II.B. Calculating ratio $\frac{\omega_1}{\omega_2}$
1. Verify relation between size of the ratio $\frac{\omega_1}{\omega_2}$ and unity and discuss the mathematical relation between I_1 and I_2, in the two positions.
2. Using equation 7.8. shall be interpreted the determinations results.
3. Measurements to recover if the skater takes in hands two weightlifting of equal masses. It interprets the outcome determinations.
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b. with weightlifting

The size of a_{y1} measured by accelerometer is:

a_{y1} = _________ m/s^2

The distance between sternum and AM in position 1:

R_1 = ___________ m

The size of the angular velocity ω_1 is:

ω_1 = ____________ rad/s

The size of a_{y2} measured by accelerometer is:

a_{y2} = _________ m/s^2

The distance between sternum and AM in position 2:

R_2 = ___________ m

The size of the angular velocity ω_2 is:

ω_2 = ____________ rad/s

7.II.B. Calculating ratio $\frac{\omega_1}{\omega_2}$

The size of ratio $\frac{\omega_1}{\omega_2}$ is:

$\frac{\omega_1}{\omega_2}$ = __________

Discussion conclusions concerning the relationship between sizes I_1 şi I_2, in the two positions and interpretation the results:

Discussion conclusions concerning comparing with results from a. without weightlifting

Analysis

Analyze the causes of friction and what impact they had on the outcome of the experiment.

Further investigation

1. **Relevance.** Students will reflect and find answers identifying possible practical role of the work done, the benefits of science and technology on life in general, the place of science in society, the social role of researcher.
2. **Connection with the real world.** Students will reflect on the practical character of their project, they will understand the importance of experimental data and the practical benefits of using the results .

Assessment

Gallery Tour: Students will prepare oral presentations to appropriate audiences, which are accompanied by multimedia presentations, brochures and websites. These products must identify current community needs and resources and provide acceptable solutions. Thus, the task turns into a learning project in support of the community, creating an authentic purpose and making a connection with the real world through community.

Evaluation criterion:

1. All team members undertake collaborative activities by completing the steps in processing aid given to them and collect data for one of the roles within the team
2. Each member fulfills the role it has in the team. Team members' work together to achieve a quality presentation
3. Presentation made meet the recommended structure.
4. Explanation contained in the presentation is enlightening to the public
5. Project presentation is eloquent and enlightening for the audience participating.
6. The manner of presentation is attractive and involving public
7. Team members are open to public questions and formulate answers all questions pertinent to public
8. Introducing the team roles demonstrates that members are knowledgeable in all fields covered by the project.
9. Team members speak out loud, communicates a very clear presentation of content, and establish eye contact with audience.
10. Team members provide additional explanations to the public request, using the flip chart

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[i] In our experiments point body is PM, oriented as shown in a horizontal plane.
[ii] In our experiments point body is PM, oriented as shown in a horizontal plane.