Physualize Experiments

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An ever-expanding list of experiments feasible with Physualize. They are classified as "**EMBODIED EXPERIENCE**" when they do not require any tools other than your own body, or as "**LAB EXPERIENCE**" when they augment an existing physics lab.

You can always find the most updated list on the dedicated page: https://www.physualize.app/experiments

I. Graph Study and Reference Systems

1. Static measurements: student's height

EMBODIED EXPERIENCE

The student positions the reference system (RS) on the ground and, holding the controller on the top of their head in a static position, acquires the vertical coordinate to determine their height, discussing the precision of the spatial measurement in AR.

2. Static measurements: desk length

EMBODIED EXPERIENCE

Positioning of the reference system (RS) at the center of the desk and acquisition of the coordinates of the ends to find the total length, discussing positive and negative values.

3. Dynamic values (Up/Down and Right/Left)

EMBODIED EXPERIENCE

The student moves the controller along the vertical and lateral axes, observing how the coordinates and graphs (for example, x(t) or y(t)) reflect the direction of movement and the choice of the reference system.

4. Scale analysis

EMBODIED EXPERIENCE

Movements along the "secondary" axes (Y or Z) relative to a graph referred to X to show background noise and the importance of the measurement scale.

5. Match Graph (Reproduction challenge)

EMBODIED EXPERIENCE

Students must move physically to try and "trace" a predefined graphic profile (e.g., moving away at constant speed, stopping, returning by running).

II. Introduction to Vectors

1. Introduction to Vectors: multiplication by a scalar

EMBODIED EXPERIENCE

The student performs a data acquisition that includes the visualization of the velocity vector. Once the vectors have been carefully observed, the visualization of the momentum vector is added by repeating the same movement. By varying the mass associated with the controller, the experiment is repeated several times to observe the effect of multiplying the velocity vector by a scalar (the mass), which results in momentum.

2. Introduction to Vectors: tangent to a curve

EMBODIED EXPERIENCE

By moving the controller on any curved trajectory, the student visualizes the velocity vector in real time (tangent to the curve at every point) and discusses the relationship between position, velocity, and vector difference.

3. Introduction to Vectors: cross product

EMBODIED EXPERIENCE

The student defines two vectors, for example the position vector r and the momentum p, and observes in real time the direction and orientation of their cross product (the angular momentum L = r x p) according to the right-hand rule. By reversing the direction of rotation, they observe that the orientation of the resulting vector L is also reversed.

III. Linear Motions

1. Free-hand Uniform Rectilinear Motion (positive velocity)

EMBODIED EXPERIENCE

The student moves the controller at a constant speed along the x-axis, moving away from the origin, and observes the x(t) graph. Then they repeat the measurement (without deleting the previous one) and observe the relationship between velocity and the slope of the line in the position-time graph.

2. Free-hand Uniform Rectilinear Motion (negative velocity)

EMBODIED EXPERIENCE

The student moves the controller at a constant speed along the x-axis, moving away from the origin for 5 seconds, then returns for another 5 seconds, observing the x(t) and $v_x(t)$ graphs. They repeat the measurement (without deleting the previous one) and observe the relationship between velocity and the slope of the line in the position-time graph.

3. Lab Uniform Rectilinear Motion (positive velocity)

LAB EXPERIENCE

The student positions the controller on a low-friction cart and studies its motion as it moves at a constant speed along the x-axis, moving away from the origin, observing the x(t) graph. Then they repeat the measurement (without deleting the previous one) and observe the relationship between velocity and the slope of the line in the position-time graph.

4. Lab Uniform Rectilinear Motion (negative velocity)

LAB EXPERIENCE

The student positions the controller on a low-friction cart and studies its motion as it moves at a constant speed along the x-axis, moving away from the origin. Once it reaches the end of its path, the cart hits a barrier and returns. The student observes the x(t) and $v_x(t)$ graphs and repeats the measurement (without deleting the previous one), observing the relationship between velocity and the slope of the line in the position-time graph.

5. Free-body Uniformly Accelerated Motion

EMBODIED EXPERIENCE

Measurement of the acceleration of gravity *g* while a student jumps.

6. Lab Uniformly Accelerated Motion

LAB EXPERIENCE

Measurement of the acceleration of gravity *g* by tracing the motion of a low-friction cart moving on an inclined plane. Is the acceleration the same if the cart is initially pushed upwards?

7. Free-body Varied Motion

EMBODIED EXPERIENCE

The student performs a complex movement (e.g., walking, running, jumping) and analyzes the position, velocity, and acceleration graphs (x(t), v(t), a(t)) to distinguish between the phases of uniform, accelerated, and rest motion, discussing how the forces change during the movement.

8. Lab Varied Motion

LAB EXPERIENCE

Transition from accelerated to uniform motion (e.g., when the weight of a pulley touches the ground).

IV. Periodic and Rotational Motions

1. Free-hand Simple Pendulum (harmonic oscillator)

EMBODIED EXPERIENCE

Holding the controller hanging from the lanyard with their hand, the student sets it in oscillation, creating a pendulum. The student observes the $x(t)$, $v_x(t)$, and $a_x(t)$ graphs (or the angular coordinates $\vartheta(t)$, $\omega(t)$, and $\alpha(t)$) that come from this simple harmonic motion. They also observe the velocity and acceleration (or force) vectors. The student then attaches weights to the controller to verify the dependence of the oscillation period on the mass, and uses a string to lengthen the pendulum to verify the dependence of the oscillation period on the length of the pendulum.

2. Free-hand Simple Pendulum (energy)

EMBODIED EXPERIENCE

The student repeats the previous experience, this time analyzing it from an energetic rather than a dynamic point of view. They observe the conservation of mechanical energy, with the transfer of energy from its kinetic form to its potential form and vice-versa.

3. Lab Simple Pendulum (harmonic oscillator)

LAB EXPERIENCE

The same experiment described in the embodied version is performed, in this case hanging the controller from a rod (or equivalent solution) so that it can oscillate with low friction (and ideally without rotating on itself while oscillating).

4. Lab Simple Pendulum (harmonic oscillator)

LAB EXPERIENCE

The same experiment described in the embodied version is performed, in this case hanging the controller from a rod (or equivalent solution) so that it can oscillate with low friction (and ideally without rotating on itself while oscillating).

5. Free-body Uniform Circular Motion

EMBODIED EXPERIENCE

The student positions the reference system exactly at the center of their own position. They extend their hand in front of them and rotate at a constant speed, keeping their position centered on the reference system, taking care not to change the distance of the controller from the center of rotation. Observing the $x(t)$ and $y(t)$ graphs, they notice that uniform circular motion is the result of the sum of two harmonic motions. From the graphs, they can find the rotation period and determine the relationship between period and angular velocity $\omega(t)$, which is also observable in a graph. Finally, they observe the velocity and acceleration (or force) vectors.

6. Lab Uniform Circular Motion

LAB EXPERIENCE

The same experiment described in the embodied version is performed, in this case fixing the controller to any object that can rotate at a constant angular velocity.

7. Lab Uniformly Accelerated Circular Motion

LAB EXPERIENCE

By fixing the controller to a rotating object (e.g., a rotating platform), the student applies a constant torque to obtain a uniform angular acceleration. They analyze the angular position $\vartheta(t)$, angular velocity $\omega(t)$, and angular acceleration $\alpha(t)$ graphs and compare them with uniformly accelerated rectilinear motion.

8. Pure Rolling

LAB EXPERIENCE

Analysis of the trajectory of an external point (cycloid) relative to the center of mass of a wheel.

V. Angular Momentum

1. Angular momentum conservation in uniform circular motion

EMBODIED EXPERIENCE

The student performs uniform circular motion holding the controller in hand. While rotating, the student observes the angular momentum and subsequently modifies the distance of the controller from the center of rotation (for example, by bringing their arms close to the body) to observe the conservation of angular momentum and the variation in angular velocity.

2. Momentum conservation in uniform circular motion

LAB EXPERIENCE

A rotating platform and a weight connected via a string and a pulley are used to study the conservation of angular momentum when the radius of rotation is changed.

3. Angular momentum conservation: insights

EMBODIED EXPERIENCE

Drawing a uniform circular motion in the air, visualizing the position, momentum, and angular momentum vectors, and observing the difference in results by modifying the position of the system's reference frame. Repeat two measurements around the origin, first rotating in one direction and then in the other, observing the constancy of the magnitude and the reversal of the direction of the angular momentum.

4. Angular momentum conservation: insights

LAB EXPERIENCE

The same experiment described in the embodied version is performed, in this case fixing the tracked object to any object that can rotate at a constant angular velocity.

5. Angular Momentum Conservation in linear motion

EMBODIED EXPERIENCE

The student moves in a straight line, visualizing the angular momentum vector relative to a reference point outside the trajectory. Conservation is observed when no external force generating torque is applied.

6. Angular Momentum Conservation in linear motion

LAB EXPERIENCE

A low-friction cart moves in a straight line. The student traces the angular momentum relative to a fixed point to demonstrate that, in the absence of friction (external torque), angular momentum is conserved.

VI. Forces and friction

1. Atwood Machine

LAB EXPERIENCE

Study of acceleration as a function of the difference in mass between two weights.

2. Measurement of Static Friction Coefficient on an inclined plane

LAB EXPERIENCE

Measurement of the critical sliding angle comparing different materials (aluminum, rubber, wood) and calculation of the coefficient of static friction as the tangent of the plane's angle of inclination.

3. Measurement of Dynamic Friction Coefficient on an inclined plane

LAB EXPERIENCE

Estimation of friction starting from the difference between the measured acceleration and the theoretical expected one.

VII. 1D and 2D Collisions

1. Collisions between carts

LAB EXPERIENCE

Analysis of elastic and inelastic collisions in 1D to verify the conservation of momentum and kinetic energy.

2. Embodied Center of Mass

EMBODIED EXPERIENCE

Automatic tracking and visualization of the CoM of a two-body system during a collision or in the motion of rotating objects (e.g., bolas).

3. Lab Center of Mass

LAB EXPERIENCE

Automatic tracking and visualization of the CoM of a two-body system during a collision or in the motion of rotating objects (e.g., bolas).

4. 2D Collisions

LAB EXPERIENCE

Use of hovercraft on air cushion tables to verify the conservation of momentum in two dimensions.

VIII. Playground physics and sports physics

1. Walking

EMBODIED EXPERIENCE

Tracking of walking (with hand fixed or swinging) and movement analysis through x(t) graphs.

2. Running biomechanics

EMBODIED EXPERIENCE

Study of vertical and horizontal oscillations of the center of mass to analyze the runner's energy efficiency.

3. Velocity-Based Training

EMBODIED EXPERIENCE

Measurement of the velocity of a dumbbell or barbell to estimate the maximum load (% 1RM).

4. Jump Analysis

EMBODIED EXPERIENCE

Calculation of the maximum height and the reactive strength index (RSI) starting from the takeoff velocity measured by the trackers.

5. Playground Physics

EMBODIED EXPERIENCE

Analysis of motion on swings, rotating rides, slides (acceleration verification), and zip lines (study of resistive forces and terminal velocity).

IX. 3D Motions

1. Complex 3D Motions

EMBODIED EXPERIENCE

Free and complex movements (e.g., throws or spiral movements) to simultaneously visualize the components of position, velocity, and acceleration in 3D.

2. Conical Pendulum

LAB EXPERIENCE

By fixing the controller to make it rotate on a cone, centripetal force, tangential velocity, and inclination angle are studied in relation to the rotation speed.

1. Precession and nutation

LAB EXPERIENCE

By fixing the controller to a rotating object (e.g., gyroscope), the phenomena of precession (change of the rotation axis) and nutation are studied.

X. Experiments with Special Accessories

1. MX Ink (Logitech)

LAB EXPERIENCE

Using the stylus as a digital dynamometer, precision scale, or pen for 3D scientific annotations directly on the real apparatus.

2. Pico Motion Trackers

EMBODIED EXPERIENCE

Body Tracking (Coming Soon)