EXPERIMENTAL PHYSICS 1

EXERCISE 4

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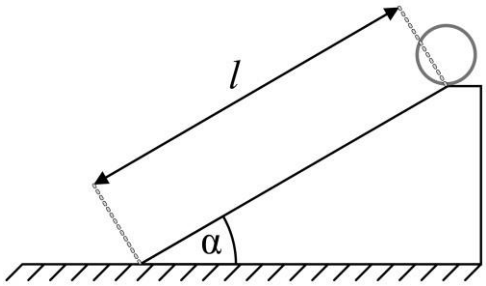
## Problem 1: Rolling Cylinders — 3+2+2+2 Points

Consider two long cylinders, one solid, the other one thin-walled, but both of outer radius $R$ and total mass $M$. Both cylinders are placed on top of an incline of length $l$ and an inclination angle $\alpha$.




a. Which cylinder arrives first?
b. Calculate the acceleration of both cylinders.
c. What is the velocity of the cylinders when arriving at the end of the incline?
d. What are the values of the angular momenta of the cylinders when arriving at the end of the incline?

$R = 5\,\mathrm{cm}$, $m = 1\,\mathrm{kg}$, $l = 1\,\mathrm{m}$, $\alpha = 30°$

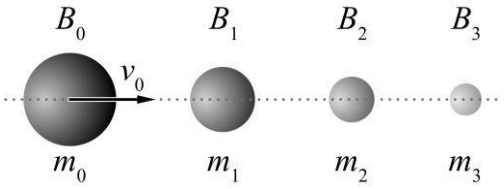
## Problem 2: Particle Collision — 2 + 2 Points

In a particle collider protons (mass $m_p = 1.67 \cdot 10^{-27}\mathrm{kg}$) are accelerated to a kinetic energy of $5\mathrm{GeV}$. Calculate the energy that is set free if,

a. A proton from the beam hits a stationary proton.
b. A proton from the beam hits a proton from another particle beam which propagates in the opposing direction

*Hint: Both collisions are perfectly inelastic.*

**Problem 3: Consecutive Collisions** **$4 + 2$ Points**




Given is the one-dimensional, procedural, elastic collision process provided in figure aside. The balls $B_1, B_2$ and $B_3$ are at rest, $v_1 = v_2 = v_3 = 0$. Ball $B_0$ has a speed of $v_0 = 1\ \mathrm{m/s}$ before colliding with ball $B_1$. The mass of the next neighbouring ball is one third of the previous ball: $m_0 = 3m_1$ , $m_1 = 3m_2$ , $m_2 = 3m_3$ .

a. Consider the first collision. Calculate the speed after the collision $v_0'$ and $v_1'$ of $B_0$ and $B_1$.
b. What is the speed $v_3'$ of $B_3$ after its collision with $B_2$?

**Problem 4: The Spinning Disk** **$3 + 1 + 2 + 1 + 2$ Points**

A solid disc with a radius of $r = 28\ \mathrm{cm}$ is centrally placed on an axis with a length of $l = 50\ \mathrm{cm}$ and a mass of $m_a = 100g$. The other end of the axis is attached to a rope. The disk has a mass of $m_d = 500\mathrm{g}$ and spins with $\omega = 12\ Hz$ (12 revolutions per second). At $t = 0$ the axis is parallel to the $y$-axis so that $\vec{\omega} = \omega \cdot e_y$. The rope is parallel to the $z$-axis so that gravity points in $-e_z$ direction.

a. Make a big, detailed sketch of the whole system. Include a coordinate system and the vectors of the angular momentum of the spinning wheel, the force and torque caused by gravity, the angular velocity of the wheel and the angular velocity of the precession movement.
b. Calculate the angular momentum of the wheel.
c. Calculate the angular speed of the precession movement
d. Calculate the time that the axis and the wheel need to make a full turn around the axis of the precession movement.
e. Calculate the magnitude and direction of the angular momentum of the precession movement.

*Hint: Make sure to use the coordinate system provided. There is a helpful video here: https://youtu.be/n5bKzBZ7XuM*

**Task to think about:**

Is there a general closed-form solution (https://en.wikipedia.org/wiki/Closed-form_expression) to the three body problem? Is their a mathematical description of the three body problem?