Exploring Configurations of a Non-Homogeneous Cylinder

Student Handout

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Background

You are given a cylinder with four secondary axes at right angles, lying in a plane perpendicular to the cylinder's main axis. On each secondary axis, a washer can be placed in one of four discrete positions:

Position 1 = close to the axis, Position 4 = farthest from the axis.

Thus, one configuration of the system can be represented as a 4-tuple, e.g.

$$(1, 1, 1, 4), \quad (4, 1, 1, 1), \quad (2, 3, 2, 3).$$

The goal is to understand which configurations are truly distinct in terms of the cylinder's physical behaviour when it rolls down an incline.

Your Tasks

Step 1: Explore the configuration space
How many different configurations are possible in total? Write down some examples explicitly.

Step 2: Search for equivalences
Compare, for example, $(4, 1, 1, 1)$ and $(1, 4, 1, 1)$. Do you expect them to produce different results? What happens if the cylinder is rotated by $90°$ before being released? Can you find other pairs or groups of configurations that should behave in the same way?

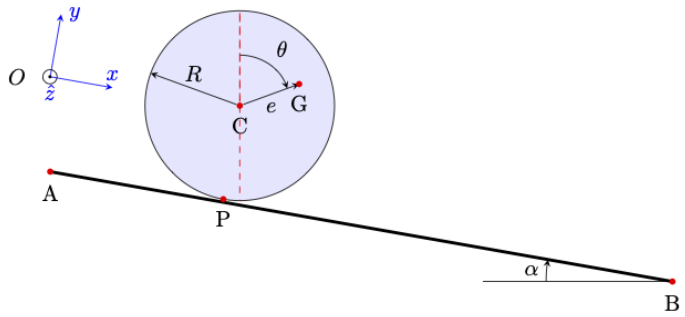

Figure 1: Schematic of the cylinder with four adjustable washers.

Step 3: Think about what really matters

The washers' positions are just one way to describe the system. Which physical effects do they generate when the cylinder rolls? Which of those effects actually influence the motion?

Step 4: Define your own descriptors

Can you propose a smaller set of "summary quantities" that would uniquely describe the cylinder's behaviour, even if different washer configurations lead to the same values?

Step 5: Towards experimental planning

Suppose you want to plan experiments efficiently. How could you use your "summary quantities" to avoid testing redundant configurations? How many experiments would you need compared to testing *all* configurations?

Hint

Sometimes different arrangements can be described by the same "hidden variables". Your task is to discover them.