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Experiment-Based Teaching Method for the Varying Frictional Coefficient

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Abstract : The topic of oscillation in physics is one of the key ideas which is usually taught based on the concept of harmonic oscillation. It can be an interesting activity to deal with a frictional oscillator in advanced high school classes or in university courses. Its mechanics are investigated in this research, which shows that the motion of the frictional oscillator is more complicated than a simple harmonic oscillator. The physics of the applied model in this study seems to be interesting and useful for undergraduate students. The study presents a well-known physical system, which is mostly discussed theoretically in high school and at the university. The ideal frictional oscillator is normally used as an example of harmonic oscillatory motion, as its theory relies on the constant coefficient of sliding friction. The structure of the system is simple: a rod with a homogeneous mass distribution is placed on two rotating identical cylinders placed at the same height so that they are horizontally aligned, and they rotate at the same angular velocity, however in opposite directions. Based on this setup, one could easily show that the equation of motion describes a harmonic oscillation considering the magnitudes of the normal forces in the system as the function of the position and the frictional forces with a constant coefficient of frictions are related to them. Therefore, the whole description of the model relies on simple Newtonian mechanics, which is available for students even in high school. On the other hand, the phenomenon of the described frictional oscillator does not seem to be so straightforward after all; experiments show that the simple harmonic oscillation cannot be observed in all cases, and the system performs a much more complex movement, whereby the rod adjusts itself to a non-harmonic oscillation with a nonzero stable amplitude after an unconventional damping effect. The stable amplitude, in this case, means that the position function of the rod converges to a harmonic oscillation with a constant amplitude. This leads to the idea of a more complex model which can describe the motion of the rod in a more accurate way. The main difference to the original equation of motion is the concept that the frictional coefficient varies with the relative velocity. This dependence on the velocity was investigated in many different research articles as well; however, this specific problem could demonstrate the key concept of the varying friction coefficient and its importance in an interesting and demonstrative way. The position function of the rod is described by a more complicated and non-trivial, yet more precise equation than the usual harmonic oscillation description of the movement. The study discusses the structure of the measurements related to the frictional oscillator, the qualitative and quantitative derivation of the theory, and the comparison of the final theoretical function as well as the measured position-function in time. The project provides useful materials and knowledge for undergraduate students and a new perspective in university physics education.

Keywords : friction, frictional coefficient, non-harmonic oscillator, physics education
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