Problem VI.2 ... rotten apple

3 points; průměr 2,22; řešilo 63 studentů

Jarda found an apple in his backpack after the FYKOS camp, which was no longer in good condition. He threw it into a low kitchen trash can 1.0 m *away, and of course, he scored a hit. He threw the apple horizontally from a height* 0.5 m, *and it landed on the spot where the wall and the base of the trash can meets, where it smashed. The basket with a mass* 910 g, *was displaced by a distance of* 5 cm *after the apple hit. What is the coefficient of friction between the floor and the basket? The apple has a mass of* 230 g. *Jarda forgot to eat his snack again.*

The problem has three parts – the flight of the apple through the air, the collision with the trash can, and the braking of the trash can due to friction with the floor. Let us denote apple's mass by $m = 230\,\mathrm{g}$ and basket's mass by $M = 910\,\mathrm{g}$.

We will solve the collision between the apple and the trash can using the law of conservation of momentum. The momentum does not change for an isolated system. Before the impact, the momentum was equal to the horizontal velocity of the apple multiplied by its mass, so $p = mv_x$. Both objects will have the same velocity after the apple hits the trash can because the collision is inelastic (the apple has smashed). Thus their momentum will be $p = (m + M)\,u$. From this, we can express their energy as

$$E_\mathrm{k} = \frac{1}{2}\,(m+M)\,u^2 = \frac{p^2}{2\,(m+M)} = \frac{m^2 v_x^2}{2\,(m+M)}\,.$$

Due to friction, this kinetic energy is converted until the trash can with the apple stops. The law of conservation of energy states

$$f = \frac{E_\mathrm{k}}{(m+M)\,gd} = \frac{m^2 v_x^2}{2\,(m+M)^2\,gd}\,,$$

where $d = 5\,\mathrm{cm}$ is the displacement of the trash can.

We still need to express the velocity

$$v_x = \frac{D}{t} = \frac{D}{\sqrt{\frac{2h}{g}}}\,,$$

which we found from the characteristics of the throw of the apple. The throw was horizontal, and the apple fell from $h = 0.5\,\mathrm{m}$ to the distance of $D = 1.0\,\mathrm{m}$.

Thus the final formula for the coefficient of friction is

$$f = \frac{m^2 D^2}{4\,(m+M)^2\,hd} \doteq 0.4\,.$$

We rounded the result to one significant digit. Firstly, because the value 5 cm in the problem assignment is also given to only one significant digit, and secondly, because of the concept of the problem assignment. In practice, it would be difficult to measure the coefficient of friction to within a hundredth using *the method of throwing rotten apples*, which is why one significant digit is more than enough.

Jaroslav Herman
jardah@fykos.org

FYKOS is organized by students of Faculty of Mathematics and Physics of Charles University. It's part of Media Communications and PR Office and is supported by Institute of Theoretical Physics of MFF UK, his employees and The Union of Czech Mathematicians and Physicists. The realization of this project was supported by Ministry of Education, Youth and Sports of the Czech Republic.