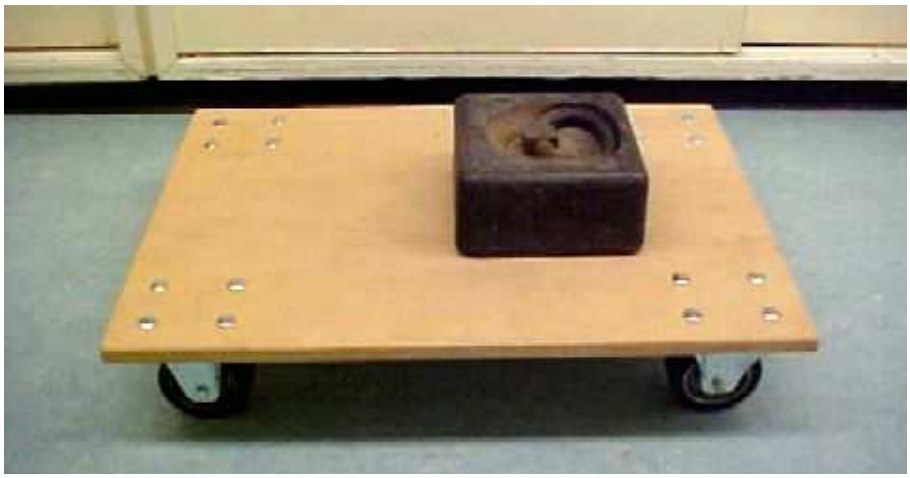
Demonstrator and cart

Title: Demonstrator and cart

Aim: To show an example in which only conservation of momentum predicts how the demonstration ends.

Subjects: 1N20 (Conservation of Linear Momentum)

Diagram:



Equipment:

- Light cart, easy rolling.
- Heavy weight ($m \approx 25kg$).
- An assistant to the demonstrator.

Demonstrator and cart

Presentation: The cart is placed centrally in front of the lecturehall. From one side the demonstrator and his assistant walk together towards the cart. Arriving at the cart the demonstrator steps on it, his assistant keeps on walking. The students will observe that the demonstrator still has the same speed; he keeps pace with the still walking assistant. The heavy weight is placed on the cart (see Diagram). Again the demonstrator and his assistant start walking towards the cart and on arrival the demonstrator steps on it (the assistant keeps on walking). Now the students will observe that the cart+demonstrator has a lower speed; the still walking assistant being his reference.

Explanation: The cart(*m*) and demonstrator (*M*) is considered as one system. Before he jumps on the cart the total impuls equals *Mv*. After he is jumped on it the total impuls equals *(M+m)v'*. So: $v' = \frac{M}{M+m} v$. When the cart is light: *v'=v* (the first part of the demonstration).
When *m* cannot be neglected *v'* will be smaller than *v*.

Remarks:

- When you step on the cart you easily give it an extra push. This should not happen. Some practicing is really needed before showing it to an audience!
- *v'* is calculated using conservation of (linear) impulse. As can be shown there is no conservation of (kinetic) energy (*K*) in this demonstration:
  Before jumping on the cart: $K = \frac{1}{2} M v^2$.
  After jumping on the cart: $K = \frac{1}{2}(M+m) v^2$, and substituting *v'* will give:
  $K = \frac{M}{M+m} \frac{1}{2} M v^2$.
  While jumping on the cart part of the energy is lost in friction. (When there would be no friction then you would glide over the cart and leave it undisturbed.) This all shows that conservation of energy cannot be used in calculating *v'*.
  (In our demonstration M=75kg and m=25kg. Conservation of impulse gives $v' = \frac{3}{4} v$, while applying conservation of energy gives $v' = \sqrt{\frac{3}{4}} v = 0.87 v$ which is wrong.)
  In calculating energy before and after it is of course possible to show how much energy is "lost" in friction.

Sources:

- Borghouts, A.N., Inleiding in de Mechanica, pag. 92-93
- Mansfield, M and O'Sullivan, C., Understanding physics, pag. 126-127
- Roest, R., Inleiding Mechanica, pag. 118-119