Tutorial 7

Problem 1. A left alone little wagon, with mass m_0, rolls with velocity $\vec{v}_0$ on straight horizontal rails. Friction, air resistance and wheel mass can be neglected. Suddenly it starts to rain, such that every second r kg water falls into the wagon. The rain falls down vertically. We consider two cases:

1. The rain remains in the wagon.
2. The wagon contains a vertical drain pipe through which water leaves the wagon. The water leaves the wagon at the same rate r kg/s as rain falls in the wagon.

a) Let $\vec{v}(t)$ be the velocity of the wagon, t seconds after it starts raining. Derive for case 1., that the acceleration $\vec{a}(t) = d\vec{v}(t)/dt$ is given by

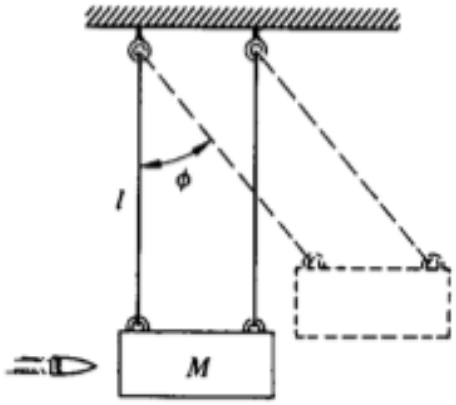
$$\vec{a}(t) = -\frac{r\vec{v}(t)}{m_0 + rt},$$

and for case 2.,

$$\vec{a}(t) = -\frac{r\vec{v}(t)}{m_0}.$$

b) Determine for both cases the velocity $\vec{v}(t)$ of the wagon, t seconds after it starts raining.

c) After how much time is the velocity reduced to $\frac{1}{2}\vec{v}_0$ in each case? Give a qualitative explanation for the difference.



Problem 2. (K. & K., 5.3) A simple way to measure the speed of a bullet is with a ballistic pendulum. As illustrated, this consists of a wooden block of mass M into which the bullet is shot. The block is suspended from cables of length l, and the impact of the bullet causes it to swing through a maximum angle ϕ, as shown. The initial speed of the bullet is v, and its mass is m.

1. How fast is the block moving immediately after the bullet comes to rest? (Assume that this happens quickly.)

2. Show how to find the velocity of the bullet by measuring m, M, l, and ϕ.