Answer on Question #78898 - Physics - Mechanics/Relativity

Question: *how do i solve this problem please help! Hailstones with an average mass of 4 g fall vertically and strike a flat roof at 12 m/s. In a period of 5 minutes 6000 hailstones fall on each square meter of roof and rebound vertically at 3 m/s. Calculate the force on the roof if it has and area of 30 m2*

The answer is 36N

Answer:

According to the second Newton's law (written in terms of momentum):

$$\vec{F} = \frac{\Delta \vec{p}}{\Delta t}, \tag{1}$$

where $\vec{F}$ is the net external force applied to a body, $\Delta \vec{p}$ is the change of momentum of a body in time Δt (caused by this force).

In the considered problem the role of a body is assigned to the system of hailstones and the force is acting on them from the side of the roof (and this is the reason of changing of their momentum). Hence, by the third Newton's law the force of the same modulus but opposite in direction acts on the roof.

Let us obtain the modulus of a force produced by a single falling hailstone (after projecting all vectors on y-axis that is supposed to be vertical):

$$F_0 = \frac{\Delta p_0}{\Delta t} = \frac{p_{20} - p_{10}}{\Delta t} = \frac{mv_2 - (-mv_1)}{\Delta t} = \frac{m(v_2 + v_1)}{\Delta t}, \tag{2}$$

where we take into account the fact that direction of the initial velocity v_1 is opposite to the direction of y-axis and, hence, its projection is negative.

In order to find the net force acting on the roof, one has to obtain the total number of hailstones falling on the roof in time Δt. As long as we have N = 6000 hailstones falling on every m^2 of the roof in t = 5 min, then the rate (or the flux) of incoming hailstones (falling on the whole roof in 1 second) is:

$$n = \frac{NS}{t}. \tag{3}$$

Then the number of hailstones falling on the roof in time Δt is equal to:

$$\Delta N = n\Delta t = NS\frac{\Delta t}{t}. \tag{4}$$

Finally, we come to the expression for the net force:

$$F_{tot} = \Delta N \cdot F_0 = NS\frac{\Delta t}{t}\frac{m(v_2 + v_1)}{\Delta t} = \frac{NSm(v_2 + v_1)}{t}. \qquad (5)$$

Substituting the letters in (5) with numbers (that should be put in SI units), we get:

$$F_{tot} = \frac{6000 \cdot 30 \cdot 0.004 \cdot (3+12)}{300} = 36N, \qquad (6)$$

which is the answer to the problem.

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