12. (a) The mass of each spherical hailstone of radius $r = 0.5$ cm and density $\rho = 0.92$ g/cm^3 is

$$m = \rho\left(\frac{4\pi r^3}{3}\right) = 0.48 \text{ g} = 4.8 \times 10^{-4} \text{ kg} .$$

(b) If the final speed is zero, then Eq. 10-4 and Eq. 10-8 (with $+y$ upward) lead to

$$\vec{F}_{\text{avg}}\Delta t = -m\vec{v}_i = -\left(4.8 \times 10^{-4}\right)(-25) = 0.012$$

in SI units (N·s). This gives the impulse imparted to a single hailstone by the roof (and is equal to the magnitude of the force on the roof by the hailstone, by Newton's third law). An imagined "cube" of falling air, $\ell = 1$ m on each side (falling with the hail at $v = 25$ m/s), takes a time of

$$\Delta t = \frac{\ell}{v} = \frac{1\,\text{m}}{25\,\text{m/s}} = 0.04 \text{ s}$$

to fully "collapse" onto a square meter of roof top (delivering its load of 120 hailstones). We can cover an area of $10\,\text{m} \times 20\,\text{m}$ with 200 of these "collapsing cubes" of air. Therefore, in this time, the total impulse is of magnitude

$$\vec{F}_{\text{avg,total}}\Delta t = 200(120)(0.012\,\text{N·s}) \approx 290\,\text{N·s}$$

which leads to $\vec{F}_{\text{avg,total}} = 290/0.04 = 7.2 \times 10^3$ N.