Meteor collision

A crater in Arizona is thought to have been formed by the impact of a meteorite with the earth over 20,000 years ago. The mass of the meteorite is estimated at 5×10^{10} kg and its speed 7200 ms^{-1}. Mass of earth = 5.98×10^{24} kg.

Judging from a frame of reference in which the earth is initially at rest, what speed would such a meteor impart to the earth in a head-on collision? Assume the pieces of the shattered meteor stayed with the earth as it moved.

Solution: The initial momentum (taking the Earth at rest initially) is

$$p_i = m_m v_m$$
$$= 5 \times 10^{10} \times 7200$$
$$= 3.6 \times 10^{14} \text{ kg ms}^{-1}$$

The final momentum, since the meteor and the Earth stick together, is

$p_f = (m_m + m_E) v_m = p_i$ since momentum is conserved.

Hence

$v_f = p_i/(m_m + m_E) \simeq p_i/m_E$ since $m_E \gg m_m$
$= 3.6 \times 10^{14}$ kg $ms^{-1} / 5.98 \times 10^{24}$ kg
$= 6.02 \times 10^{-11}$ ms^{-1}
$= 0.019$ m yr^{-1}
$= 1.9$ mm yr^{-1}