Comet Shoemaker Levy and Earth

Comet Shoemaker-Levy struck Jupiter in 1994. The result was an inelastic collision, where the comet "stuck" to Jupiter, actually becoming part of its atmosphere. Given the velocities of Jupiter and the comet, $v_J = 1.3 \, x \, 10^4 \, m/s$, $v_C = -6.0 \, x \, 10^4 \, m/s$, and the mass of Jupiter and the comet, $m_J = 1.9 \, x \, 10^{27} \, kg$, $m_C = 4.0 \, x \, 10^{12} \, kg$, this situation can be expressed mathematically:

$m_C v_C + m_J v_J = (m_C + m_J) v_f$ — inelastic collision

$v_f = v_J + \Delta v$ — where Δv is the change in Jupiter's velocity caused by the impact

$m_C v_C + m_J v_J = (m_C + m_J)(v_J + \Delta v)$ → $m_C v_C + m_J v_J = m_C v_J + m_C \Delta v + m_J v_J + m_J \Delta v$ →

$m_C v_C = m_C v_J + m_C \Delta v + m_J \Delta v$ → $m_C v_C - m_C v_J = m_C \Delta v + m_J \Delta v$ →

$m_C (v_C - v_J) = (m_C + m_J) \Delta v$

$$\Delta v = \frac{m_C (v_C - v_J)}{m_C + m_J} = \frac{(4.0 \, x \, 10^{12} kg)(-6.0 \, x \, 10^4 m/s - 1.3 \, x \, 10^4 m/s)}{4.0 \, x \, 10^{12} kg + 1.9 \, x \, 10^{27} kg} = -1.5 \, x \, 10^{-10} m/s$$

since this number is negative it means that Jupiter slowed down by that velocity

If Comet Shoemaker Levy had hit Earth instead how would it have changed Earth's velocity? You know that the mass of the Earth is $m_E = 5.98 \, x \, 10^{24} kg$ and the radius of the Earth's orbit is $r_E = 1.49 \, x \, 10^8 km = 1.49 \, x \, 10^{11} m$

1) Rewrite the last equation for Δv above, replacing *J* with *E*.

$$\Delta v = \frac{m_C (v_C - v_E)}{m_C + m_E}$$

2) Calculate the circumference of the Earth's orbit around the Sun. Assume that the orbit is circular.

$$C_E = 2\pi r_E = (2)(3.14)(1.49 \, x \, 10^{11} m) = 9.36 \, x \, 10^{11} m$$

3) How many seconds does it take for Earth to complete one orbit around the Sun?

$$t_E = 1 \, year \; x \; \frac{365.25 \, days}{1 \, year} \, x \, \frac{24 \, hr}{1 \, day} \, x \, \frac{60 \min}{1 \, hr} \, x \, \frac{60 \, s}{1 \min} = 3.16 \, x \, 10^7 s$$

4) Calculate Earth's orbital velocity around the Sun.

$$v_E = \frac{C_E}{t_E} = \frac{9.36 \, x \, 10^{11} m}{3.16 \, x \, 10^7 s} = 2.96 \, x \, 10^4 m/s$$

5) Calculate the change in Earth's velocity.

$$\Delta v = \frac{(4.0\ x\ 10^{12}\ kg)(-6.0\ x\ 10^{4}\ m/s - 2.96\ x\ 10^{4}\ m/s)}{4.0\ x\ 10^{12}\ kg + 5.98\ x\ 10^{24}\ kg} = -5.99\ x\ 10^{-8}\ m/s$$

6) What does the sign of this number tell you about Earth's change in velocity?

Since this number is negative it means that Earth slowed down by that velocity.