



On July 4, 2005 at 5:45 UT the 362-kilogram Impactor from NASA's Deep Impact mission, collided with the nucleus of the comet Tempel 1, causing a bright flash of light and a plume of ejected gas (see photo).

Traveling at 10.3 km/sec, the Impactor created a crater on the nucleus and ejected about 10,000 tons of material.

The average density of the comet nucleus is 400 kg/m^3 and its size can be approximated as a sphere with a radius of 3 kilometers.

Problem 1 – From the information given, what was the approximate mass of the comet nucleus in kilograms?

Problem 2 - If the Impactor's path was perpendicular to the path taken by the Comet's nucleus, conservation of momentum requires that the product of the mass of the Impactor and its speed perpendicular to the orbit must equal the product of the comet's mass and the comet's speed perpendicular to the orbit after the impact assuming no mass loss. Although the impact ejected 10,000,000 kilograms of comet material, we will ignore this effect since the comet's mass was over 45 trillion kilograms! From the information, what is the final speed of the comet nucleus perpendicular to its orbit in A) kilometers/sec? B) meters/year?

Problem 3 – How far, in kilometers, will the comet nucleus have drifted 'sideways' to its orbit after 1 million years?

Problem 4 – Suppose that the comet had been headed toward Earth, and it was predicted that in 50 years it would collide with Earth. A nuclear bomb with an explosive yield equal to 10 million tons of TNT is launched to intercept the comet nucleus and deliver a blast, whose energy is equal to that of a 7.5×10^8 kilogram Impactor traveling at 10.3 km/sec. Assuming that the nucleus is not pulverized, A) about how far, in kilometers, will the nucleus drift after 20 years? B) Is this enough to avoid hitting Earth (diameter = 12,000 kilometers)?

Problem 1 – From the information given, what was the approximate mass of the comet nucleus in kilograms?

Answer: The spherical volume was $V = 4/3 \pi (3000 \text{ meters})^3 = 1.1 \times 10^{11} \text{ meters}^3$. The density was 400 kg/m^3 , so $\text{Mass} = \text{Density} \times \text{Volume} = 400 \times 1.1 \times 10^{11} = 45 \text{ trillion kilograms}$.

Problem 2 -- If the Impactor's path was perpendicular to the path taken by the Comet's nucleus, conservation of momentum requires that the product of the mass of the Impactor and its speed perpendicular to the orbit must equal the product of the comet's mass and the comet's speed perpendicular to the orbit after the impact assuming no mass loss. Although the impact ejected 10,000,000 kilograms of comet material, we will ignore this effect since the comet's mass was over 45 trillion kilograms! From the information, what is the final speed of the comet nucleus perpendicular to its orbit in A) kilometers/sec? B) meters/year?

Answer: A) $V_c = m_i V_i / M_c = (362 \text{ kg}) \times (10.3 \text{ km/sec}) / 45 \text{ trillion kg} = 8 \times 10^{-11} \text{ kilometers/sec}$.

B) $8 \times 10^{-11} \text{ km/s} \times (1000 \text{ m/km}) \times (3600 \text{ s/hr}) \times (24 \text{ hr/day}) \times (365 \text{ d/yr}) = 2.5 \text{ meters/year}$.

Problem 3 – How far, in kilometers, will the comet nucleus have drifted sideways to its orbit after 1 million years?

Answer: From Problem 2, the drift is 2.5 meters/year, so after 1 million years the nucleus will have drifted about 2,500,000 meters or **2,500 kilometers**.

Problem 4 – Suppose that the comet had been headed towards Earth, and it is predicted that in 50 years it will collide with Earth. A nuclear bomb with an explosive yield equal to 10 million tons of TNT is launched to intercept the comet nucleus and deliver a blast, whose energy is equal to that of a 7.5×10^8 kilogram Impactor traveling at 10.3 km/sec. Assuming that the nucleus is not pulverized, A) about how far, in kilometers, will the nucleus drift after 20 years? B) Is this enough to avoid hitting Earth (diameter = 12,000 kilometers)?

Answer: Using $m_i V_i = m_c V_c$, we get

$$\begin{aligned} V_c &= (7.5 \times 10^8 \text{ kilograms}) \times (10.3 \text{ km/sec}) / 45 \text{ trillion kg} \\ &= 0.00017 \text{ kilometers/sec.} \end{aligned}$$

A) In 20 years ($20 \times 3.1 \times 10^7$ seconds) it travels **100,000 kilometers**.

B) **Yes**, since it only needs to travel 12,000 kilometers sideways to avoid hitting Earth, the detonation did help to avoid the collision...assuming the comet wasn't fragmented into a large cloud of debris!