Between 4.1 and 3.8 billion years ago, the surfaces of all the planets were being bombarded by asteroids and other large bodies called impactors that had formed in the solar system by this time. Astronomers call this the Late Heavy Bombardment Era, and it is the era which finalized the formation of the planets at their present sizes.

The surface of our moon shows many large round basins called mare that are all that remains of this era. Similar scars on Earth have long since vanished due to erosion, volcanism and plate tectonic activity.

Problem 1 – Using the large crater and impact basin record on the lunar surface, astronomers can estimate that Earth had about 20,000 craters over 20 km across, about 50 impact basins with diameters of 1,000 kilometers, and perhaps 5 large basins with diameters of 5,000 kilometers. If the Late Heavy Bombardment Era lasted about 300 million years, how many years elapsed between the impacts of each of the three kinds of objects during this era?

Problem 2 – A Rule-of-Thumb says that the actual diameter of an impacting body is about 1/6 the diameter of the crater it forms. What were the average sizes of the three kinds of impactors during this Era?

Problem 3 – Use the formula for the volume of a sphere to calculate A) the total volume added to Earth of the small impactors in cubic kilometers. B) the total volume added to Earth of the medium-sized impactors in cubic kilometers. C) the total volume added to Earth of the large impactors in cubic kilometers.

Problem 4 - If the radius of Earth is 6,378 km, what percentage of Earth's volume was added by each of the three kinds of impactors?

Problem 1 – Using the large crater and impact basin record on the lunar surface, astronomers can estimate that Earth had about 20,000 craters over 20 km across, about 50 impact basins with diameters of 1,000 kilometers, and perhaps 5 large basins with diameters of 5,000 kilometers. If the Late Heavy Bombardment Era lasted about 300 million years, how many years elapsed between the impacts of each of the three kinds of objects during this era?

Answer: Small: 300 million/20,000 = **15,000 years**. Medium: 300 million/50 = **6 million years**, Large: 300 million/5 = **60 million years**.

Problem 2 – A Rule-of-Thumb says that the actual diameter of an impacting body is about 1/6 the diameter of the crater it forms. What were the average sizes of the three kinds of impactors during this Era?

Answer: Small = 20 km/6 = **3 km**. Medium: 1000 km/6 = **166 km**. Large: 5000km/6 = **833 km**.

Problem 3 – Use the formula for the volume of a sphere to calculate A) the total volume added to Earth of the small impactors in cubic kilometers. B) the total volume added to Earth of the medium-sized impactors in cubic kilometers. C) the total volume added to Earth of the large impactors in cubic kilometers.

Answer: $V = 4/3\ \pi\ R^3$ and there were 20,000 of these so
Small = 20,000 x 4/3 x 3.141 x $(3\ km/2)^3$ = **282,000 km^3**
Medium: There were 50 of these so $V = 50 \times 4/3 \times 3.141 \times (166\ km/2)^3$ = **120 million km^3**
Large: There were 5 of these so $V = 5 \times 4/3 \times 3.141 \times (833\ km/2)^3$ = **1.5 billion km^3**

Problem 4 - If the radius of Earth is 6,378 km, what percentage of Earth's volume was added by each of the three kinds of impactors?

Answer: The total volume of a spherical Earth is V = 4/3 x 3.141 x $(6378)^3$ = 1.1 trillion km^3

So the three kinds of impactors contributed:

Small = 100% x (282000/1.1 trillion) = **0.00003 % of the final volume**.
Medium = 100% x (120 million/1.1 trillion) = **0.01 % of the final volume**.
Large = 100% x (1.5 billion/1.1 trillion) = **0.13% of the final volume**.

So the infrequent (every 60 million years) but largest impactors changed Earth's size the most rapidly during the Late Heavy Bombardment Era!