SOME THINGS ARE CONSERVED

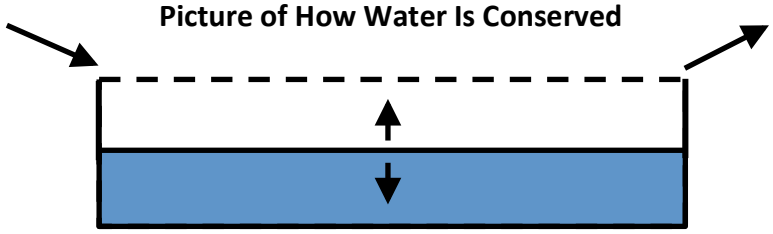
With a region of space defined surrounded by some boundary, then something, X, is "conserved" during a certain interval of time if, and only if, it obeys this equation:

(X in region, initially) + (X entering boundary – X exiting boundary) = (X in region, finally)

I. How the universe conserves things:

Imagine a region of space; say a tank, like an aquarium filled with water (see the figure below).

Picture of How Water Is Conserved



(Water inside @ start) + (Water that Flowed In – Water that Flowed Out) = (Water inside @ end)

Let's say for simplicity the only way to change the amount of water in the tank is by pouring some in or by some evaporating out. This equation applies to any specific interval of time.

II. Use it

1. At 12pm there are 100 Liters (L) of water in the tank in your lab, then you add 1 L. There isn't enough time for any to evaporate out. You then re-measure how much is in the tank just after you pour in the water. Fill in the values for each term in the conservation of water equation.

Water Inside (initial) = _____

(Water that Flowed In – Water that Flowed Out) = _____

Water Inside (final) = _____

Let's call the middle term in parentheses the water transfer term, which is made up of 2 parts: what flows in and what flow out.

a. Is it possible to find how much water flowed in during this interval? If so, how much was it?

b. Is it possible to find out how much water flowed out during this interval? If so, how much was it?

2. You watch the tank carefully to make sure nobody else in your lab pours any water in. While just after 12pm there was 101 L in the tank, by the end of the day, you find there are 100L.

Water Inside (initial) = _____

(Water that Flowed In – Water that Flowed Out) = _____

Water Inside (final) = _____

   a. Is it possible to find how much water flowed in during this interval? If so, how much was it?

   b. Is it possible to find out how much water flowed out during this interval? If so, how much was it?

3. At 5pm there are 100 L of water. You leave and return the next morning at 8am to find that there are 120 L in the tank. Write the value that each term is equal to in the conservation of water equation.

Water Inside (initial) = _____

(Water that Flowed In – Water that Flowed Out) = _____

Water Inside (final) = _____

   a. Is it possible to find how much water flowed in during this interval? If so, how much was it?

   b. Is it possible to find out how much water flowed out during this interval? If so, how much was it?

III. Our universe vs. some other logically possible universe

(X in region, initially) + (X entering boundary – X exiting boundary) = (X in region, finally)

This is how the universe conserves something, when it does. When you actually try to apply it, it is very intuitive. But this isn't the ONLY way the universe could conserve something. This equation above applies to "local" conservation. Local conservation obeys 2 rules.

4. **(Rule 1)** Would this equation be true if water could spontaneously vanished into nothingness? How about if it spontaneously appeared inside of the boundary out of nothingness?

5. **(Rule 2)** Would this equation be true if water could teleport to outside of the boundary without crossing it?

To be conserved for some amount of time, something needs to exist the entire time. It doesn't pop out of nowhere, and it doesn't disappear. If it moves from place to place, it doesn't jump around randomly; it follows a smooth, continuous path between the first place and the second. **Some things are conserved only SOME of the time; VERY few things are conserved ALL OF THE TIME.**

6. If an object followed Rule 2, but not Rule 1, would it make sense to say this object is conserved?

7. If an object followed Rule 1 but not Rule 2, would it make sense to say this object is conserved?

8. Were people conserved in the activity you performed earlier?

9. Are people always conserved?

10. Was water conserved during the thought experiments we did earlier?

11. Is water always conserved? You may need the Internet as a resource.

12. If we picked the boundary for our conservation equation as surrounding the entire Earth and its atmosphere, could it be gaining or losing water? You may need the Internet as a resource.

13. Categorize the following things by whether the universe conserves them always, some of the time, or never. If the universe conserves the thing only some of the time, give an example when it is conserved and another example when it isn't. Use the Internet as a resource.

    a. Molecules –

    b. Atoms -

    c. Subatomic particles such as electrons, protons, neutrons -

    d. Charge -

    e. Mass -

    f. Energy -

    g. Momentum -

    h. Angular momentum -