Topics: Earth's interior, Earth's atmosphere including hydrostatic equilibrium, and the Moon

Reading:

- Read pp. 221 - 230 of Ryden and Peterson (the end of Ch. 9, including the appendix on radioactive dating).

Summary of work to submit:

- Nothing to submit for Thursday's class.

Overview:

Why doesn't the Earth's atmosphere collapse down into a very dense, very thin layer along the ground? Why don't we feel the weight of hundreds of pounds of air on our heads? *It is pressure gradients that lead to forces, not pressure itself.* The Earth's atmosphere (and any atmosphere in hydrostatic equilibrium (HSEQ)) rearranges itself so as to set up a pressure gradient that balances gravity (or the weight of the atmosphere above it), according to eqn. 9.8. HSEQ generally holds in the atmospheres of other planets, moons that have atmospheres, and even gas giant planets and stars. Note that HSEQ tends to make the lower parts of an atmosphere dense and upper parts low density. We'll double back to the reading about the Earth's interior after we discuss its atmosphere. And then we'll look at the key properties of the Moon. We'll compare and contrast it to the Earth. And those facts will provide clues about how the Moon formed.

Commentary on the reading, viewing, and other preparation:

I am repeating here some of the information at the end of the last assignment, mostly taking out stuff we already talked about.

The perfect gas law in its most useful form for astronomy is eqn. 9.9 on p. 215. But it probably doesn't look familiar to you. Another simple form of the gas pressure is $P = nkT$, where n is the number density of particles (particles per cubic meter). But the form in the book has the mass density, ρ (kilograms per cubic meter). What is the relationship between number density and mass density? See if you can figure it out. Looking at the units will help. So, the "mean molecular mass" given by the Greek letter μ is the average particle's mass expressed in units of the proton mass. Note that protons and neutrons have virtually the same mass and electrons weigh only 1/2000 as much, so we can generally ignore their mass. A hydrogen atom has one proton and one electron so it has $\mu = 1$. While helium has two protons, two neutrons, and two electrons, for $\mu = 4$.

The equation of HSEQ (eqn. 9.12) is a differential equation (an equation with variables but also at least one derivative of a variable). You solve it by integrating both sides. The book does it for a special case (gravity and temperature both constant). We'll go over that at the end of class, but you should read it carefully, see if it makes sense to you, and note that once you solve the HSEQ equation, you have an equation for pressure as a function of height in the atmosphere (eqn. 9.14). From that, you can calculate, for example, what the air pressure is on the top of Mt. Everest.

So...the answer is that atmospheres hold themselves up against gravity not by pressure itself, but by the *gradient* of the pressure (that is, the spatial derivate of the pressure, or crudely, pressure differences). Air pressure makes air move only when there is a pressure *difference.*

Note that a gradient is a derivative with respect to location. It answers questions like, "how much does the pressure of the Earth's atmosphere change as I go up 100 meters in altitude?" The air pressure gradient in the horizontal direction dictates how fast the wind blows. As an aside, the gravitational force is the gradient of the gravitational potential. Gradients are all over the place.

This is new:

The Moon's composition is sort of like the Earth's and sort of not (lower density, many compounds in common but not all). It's like the Moon was formed out of the same stuff the outer half of the Earth is made of but none of the stuff in its core.

One fundamental difference between the Moon and Earth is its smaller size and mass, which led it to cool much more quickly. And also makes it devoid of any atmosphere.

Among other things, the lack of atmosphere means that there is no erosion and so the record of meteor impacts (craters) is preserved. The Earth has even more impacts than the Moon, but ours get eroded away pretty quickly. There's a famous crater in Arizona, but it's only 25,000 years old. Meteors are important in the big picture because they are a natural consequence of our theory of Solar System formation. If the planets formed from planetessimals in the disk sticking together, there must be some left over ones that orbit around the Solar System, occasionally crashing into things. And over time, those objects are reduced in number (since once they crash into planets and moons they are no longer orbiting around) and so we expect an era of early bombardment in the Solar System, when there were a lot more meteor strikes and cratering. Maybe even big collisions between planet-sized objects...

So, it seems that the Moon formed when a Mars-sized object collided with the Earth, soon after it formed. Why is that the favored theory? What evidence is there in its favor?

Finally – but importantly – radioactive dating. Useful for all sorts of things. Recall that each element has isotopes (varieties with more or fewer neutrons) some of which are often radioactive. That means they undergo spontaneous reactions in their nuclei that give off energy and result in one isotope being changed into another or even into another element.

If you know how much of a radioactive substance there was at one time, and then you measure less of it at a later time, you can figure out how much time has passed if you know the rate at which it decays. The governing equation is 9.26. Translate that equation into words! You can use the word "proportional" and eliminate the equal sign and constant of proportionality from your translation.