UCF Physics: AST 6165 Planetary Atmospheres

Spring 2020 Final Examination

Special at-home instructions:

1. This exam is being administered at home. During the administration, you must neither seek, send, nor receive information or communication of any kind from any source, including other people, the internet, books, notes, etc., except as indicated below. As you are aware, the UCF Golden Rule honor code applies and has severe consequences for violations.
2. You are responsible for providing the testing environment you require.
3. You may communicate with the instructor by telephone or text. The instructor may communicate responses individually or to the entire class.
4. The standard testing interval is 3 hours. The exam starts at 2:00 pm on Thursday April 23. Give yourself three hours exactly (or the correct interval if you have an accommodation), then stop writing and erasing.
5. When you are done or out of time, upload a legible image of every exam page, in order, as a single PDF file in WebCourses. You will have about 15 minutes to do this, and you must do it immediately.

UNDERSTAND THE SCORING RULES:

1. Grading will be out of (no more than) 130 points, to a maximum of 110%.
2. One third of incorrect points on attempted questions will be deducted from the total correct points. For example, if a question is worth 20 points and you get 14/20 correct, it is recorded as 12 points.
3. Write "do not count" at the top of any answer you do not wish to have considered.
4. All subparts of multi-part problems count.
5. Questions with a * are required.
6. At least 2 questions from the open-book section are required.

Other Rules:

1. Give complete answers that address the question. For example, if the question asks, why is X brighter than Y, don't say, "It's hotter," say "It's hotter. The Planck function says hot things are brighter than cool things."
2. Justify all answers completely, but as briefly as you can.
3. In general, explanations require a small number of sentences, not paragraphs.
4. **Derive a mathematical expression for the answer before plugging in numbers. Show all work if you wish to receive partial credit for incorrect answers.**
5. No calculation devices are allowed.
6. Use one significant digit in your final answers, but preserve precision as much as you reasonably can in the steps leading to those answers.
7. Write your name on each answer page.
8. Record your start time, time part 2 started, and end time.
9. **Do not write on this exam, not even your name or scratch notes.** It will be discarded and not graded.

Write down the time you sarted.

1. * (5 points) In the 2004 climate-thriller movie *The Day After Tomorrow*, giant storms with huge central eyes form in the northern hemisphere. When the eye of one of these storms arrives, extremely cold air from the stratosphere descends, freezing everything — including people — solid in a matter of seconds. What's wrong with this (motion) picture?

2. "Dark energy" is the name given to the universe's evidently accelerating expansion. Is it an appropriate term?

   (a) (5 points) What kind of quantity is PV, the left side of the ideal gas law? Use a units argument.

   (b) (5 points) Do the same using a separate physical argument.

   (c) (5 points) How does the instantaneous acceleration of an uncontained gas relate to this quantity? So, is "dark energy" an appropriate term? What other term would be at least as appropriate and more intuitive (but way less "sexy")?

3. (5 points) A stationary weather pattern over a city in a sunny climate often leads to a tropospheric inversion layer. These trap air and pollution. Why would such inversions preferentially form over cities?

4. (5 points) If you look inside a chamber whose contents are in local thermodynamic equilibrium, what do you see and why?

5. * Material Derivative. (I am looking for a short paragraph of description. Do not just recite the terms. Do not derive it mathematically. Explain what's going on in each term, and why.)

   (a) (5 points) Describe in words what the material derivative is for and why it needs to appear in the governing equations of fluid dynamics and

   (b) (5 points) how each term it works.

6. * (10 points) How does the [C]/[O] ratio affect atmospheric chemistry on a gas giant? What molecules would you expect if [C]>[O] and if [C]<[O]? Why?

7. (5 points) Do reaction rates rise or fall as pressure increases? What is the physical reason for this?

8. * (10 points) Sketch a cutaway of a gas giant and an ice giant interior to scale. Label all the parts, their main constituents, and the state of matter in each part. Indicate where the magnetic field is generated.

9. * (2x2x5 points) Name and in 1-2 sentences describe the physics of five mechanisms for adding and five mechanisms for removing chemicals from an atmosphere. Mechanisms must be physically distinct from one another. If a mechanism affects only some species or types of atmosphere, name them.

10. Rossby waves:

    (a) (5 points) Describe the oscillation process of a planetary (Rossby) wave. What mechanism changes the direction of the wind?

    (b) (3 points) What are three phenomenological (appearance and behavior) characteristics of observed Rossby waves?

    (c) (2 points) Can we observe Rossby waves in westward flows? Why or why not?

11. (10 points) On a hot-Jupiter exoplanet, what two time scales are in competition to take heat away from the substellar hot spot, and how can you use them to predict the temperature of the night side?

If you hand in the problems above, you may now use the book and notes in paper or electronic form. You may not use the internet.
For these problems, calculate to one digit accuracy (only) in the final answer. Leave things like logs, powers, and roots in simplest form if not easily calculated. Or, you **may** use your electronic device as a calculator, or use a regular calculator, only in this section.
Write the time you started this section.

12. (15 points) An atmosphere has an optically thick abyssal (deep) layer, the top of which is at 200 K, and a troposphere in which the temperature decreases to around 170 K. Rather than a stratosphere, there is just an isothermal layer at 170 K, topped by a hot thermosphere in which the temperature reaches 400 K before it is too thin to emit much. Composition is homogeneous. The isothermal region extends from 1.000010 bar to 10 μbar, $g = 25$ m/s^2, $M_{mol} = 2.5$ g/mol, $\rho_{1bar} = 1$ kg/m^3. The extinction coefficeint is 2.5×10^{-3} m^2/kg at a particular wavelength. What is the optical thickness of the isothermal region at this wavelength? Write down an expression for the fraction of light that passes from the abyssal layer to the thermosphere.

13. * Red giant's peak wavelength

    (a) (5 points) Derive an expression for the peak wavelength of a star given its luminosity and radius.

    (b) (5 points) If a star going through its red-giant phase experienced a radius increase by a factor of 4 while the luminosity remained constant, how would that affect its peak wavelength?

14. * A large, stable high-pressure system forms in the Gulf of Mexico near New Orleans at 30° north latitude. It has a diameter of 300 km and winds of 150 km/h. Deflected by a passing high-pressure area over Louisiana, it heads exactly southeast at 141 km/h. The radius of the Earth is 6400 km.

    (a) (5 points) What is the relative vorticity near New Orleans?

    (b) (5 points) What will it be when the system reaches 10° south latitude?

15. (15 points) Assuming geostrophy, find the wind speed and direction at 30° N, where pressure on a horizontal surface increases at 1 mPa/m (1 mbar/100 km) toward the north and the pressure and temperature are, respectively, 781 mbar and 273 K.

Write the time you ended the exam.
Put your name on every page.