PRINCETON UNIVERSITY PHYSICS COMPETITION

GENERAL INFORMATION

Online Part

Guidelines

Student teams will have a total of **one week** to complete the exam from start to finish. We recommend that teams set aside approximately 20 hours to allow enough time for successful completion. All teams are required to submit their response with a cover page listing the title of their work, the date, and the information provided during registration. Additionally, it should include the signatures of all contestants on that team. Each submitted page should also have on it the team ID number and problem number. All other formatting decisions are delegated to the teams themselves, with no one style favored over another. While points will not be deducted for written work, we suggest that teams use a typesetting language (e.g., LaTeX) or a word-processing program (e.g., Microsoft Word/Pages) for convenience. There will be three types of problems on the online exam, with about twenty questions in total:

- **Introductory:** These questions will introduce students to the research topic. No prior knowledge is assumed.
- **Intermediate:** Questions that will bring students up to date with current physics research that assume knowledge of the introductory material and questions.
- **Research:** As the most difficult questions on the exam, research questions will test students' knowledge and creativity in manipulating and interpreting data from current research.

Collaboration Policy

Students participating in the competition may only correspond with other members of their team. No other correspondence is allowed, including: mentors, teachers, professors, and other students. While teams are allowed to use a plethora of online resources, participating students are barred from posting content or asking questions related to the exam.

Resources

Barring violating the collaboration policy, students have access to the following types of resources:

- **Online**: Teams may use any information they find useful on the Internet. However, under no circumstances may they engage in active interactions such as posting content or asking questions regarding the exam.
- **Published Materials**: Teams may take advantage of any published material (print/online)
- **Computational**: Teams may use any computational resources they might find helpful, such as Wolfram Alpha/Mathematica, Matlab, Excel, or lower level programming languages (C++, Java, Python, etc).

Citations

All student submissions with outside material must include numbered citations. We do not prefer any style of citation in particular. Students may find the following guide useful in learning when to cite sourced material:

http://www.princeton.edu/pr/pub/integrity/pages/cite/

Submission

Teams must submit their Online Part solutions by e-mailing pupc.submit@gmail.com in accordance with the Test Rules before 2 PM Eastern Time (UTC-5) on Saturday, November 22, 2014. Teams will not be able to submit their solutions to the Online Part at any later time. Regardless of internal formatting, solutions should be submitted as a single PDF document with the ".pdf" extension. The e-mail must contain your team ID in the Subject field. Only one person per team, identified as the "team manager" during registration, should send this e-mail. (Team managers will receive their team ID via e-mail before the Online Part is released.) Each submitted page should also have on it the team ID number and problem number, and the front page should include the signatures of all contestants in that team. Any discrepancies will be dealt with by the current Director of PUPC.

Sample Problems

Below are sample questions (all three types) related to stellar formation. The example topic is not necessarily related to those of the competition. Additionally, the sample questions are considerably shorter than questions on the actual exam. Teams are recommended to look over the problems at least briefly.

1. Consider a spherical star with uniform density, mass M and radius R, in hydrostatic equilibrium. Derive expressions for its thermal and gravitational potential energies.
2. Based on the temperature of a white dwarf, estimate the average energy of atoms inside the star. Are the atoms ionized or not?
3. Is the degenerate electron gas inside a white dwarf non-relativistic, somewhat relativistic, or ultra-relativistic?

4. Given the numerical data in the table below, find a relation between the mass and radius of a white dwarf. The first column contains the logarithm of the central density, the second one gives the mass in units of M_{Sun}, and the third one gives the radius in units of R_{Sun}. Does the derived relation agree with your analytic model? What can you say about the dynamical stability of a white dwarf from the mass-radius relation?

$\log\rho_c$	M/M_{Sun}	R/R_{Sun}
4	0.04811	0.03448
5	0.14600	0.02339
6	0.39366	0.01566
7	0.80146	0.01013
8	1.16176	0.00619
9	1.34619	0.00353
10	1.41096	0.00188

5. What keeps a white dwarf from collapsing? What happens as the temperature approaches 0 K? (Hint: think about the Pauli Exclusion Principle)

6. The mass of a white dwarf is inversely proportional to its volume, so the more massive white dwarfs are actually smaller! Explain where this relation comes from. Why is it so surprising and what are the implications of this dependence?