



## Physics Unlimited Explorer Competition

January 2020

**Guidelines:** The assignment consists of one open-ended section, which you will be given 1 full week to complete. Collaboration only among your team members is allowed. We recommend that teams set aside at least 10 hours to allow enough time for successful completion. Please refer to the submission explanation below for details on both formatting and the submission process.

Some useful tips and requirements:

- You may not be able to complete the entire assignment. Do not worry, as all works will be judged relative to each other. A significant amount of partial credit can be granted for reasonable explanations. Our goal with this assignment is to provide an opportunity for you to develop your thoughts in a coherent manner and to gain experience in writing up a scientific research paper. (Perhaps you might wish to consider publishing a version of your work after the completion of this competition or use it as a basis for further study!)
- Use symbols rather than numbers wherever possible and check units.
- Wherever possible, check whether an answer or intermediate result in your calculations makes sense before moving on.
- If you get stuck on an early part of a calculation, and a later part depends on it, clearly define a symbol for the unknown answer and use it in later parts.
- Under no circumstances may teams actively post content or ask questions about the assignment other than through the Piazza page linked to below.
- 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).
- Teams may take advantage of any published material, both printed or online. However, the requirement is that *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/>.
- Piazza page: Teams are encouraged to create an account on Piazza and register in the class at the following URL: <http://piazza.com/physicsu.org/spring2020/ec2020>. This resource can be used by teams to ask questions about the content of the assignment. Please do not post any of your work, partial or complete, when asking questions on Piazza, as it may be grounds for disqualification.

To receive full credit you need to show your work! Partial credit will be awarded at the judges' discretion.  
**Good luck!**

## Grading

Students are encouraged to work on as much of the assignment as possible to produce a clean and thought-out paper. However, even partial submissions will likely receive credit, so please do not get discouraged if you run out of time and be sure to submit your work regardless. The award structure will be as follows:

- a. Awards will be given to the three teams (submissions) with the highest scores as agreed upon by the judges (an award for first place, second place, and third place).
- b. Special award(s) may also be given for honorable mention(s), the most elegant work, and the most creative work, based on the number of submissions received and at the judges' discretion.
- c. All participants will receive electronic Certificates of Participation. All award winners will receive electronic PDF versions of award certificates, and their names will be posted on the Physics Unlimited website and our official social media accounts (unless you choose to opt out of public recognition).
- d. In addition, beginning this year we will actively contact and submit entries about the winners and teams who distinguish themselves in the Explorer Competition to the local press (print and/or online media outlets) based in the locations where the competitors live or study.

## Submission

All submissions, regardless of formatting, should include a cover page listing the title of their team, the date, and signatures of all team participants. (Electronic signatures are acceptable.) The work must be submitted as one single PDF document with the .pdf extension. All other formatting decisions are delegated to the teams themselves, beyond the requirements specified in the assignment. No one style is favored over another. That being said, we *strongly* recommend that teams use one of the freely available typesetting programs to gain experience with L<sup>A</sup>T<sub>E</sub>X. Handwritten work is allowed as last resort, but keep in mind that we may not be able to award significant credit to such submissions. Note: we reserve the right to refuse grading of any portion of a teams submission in the case that the presentation of the solution is illegible.

Teams must submit their Explorer Competition papers by having each team member follow a simple process specified in a form that will be released on the Physics Unlimited website one week from the time the assignment is posted. Each member will be asked to briefly state which part of the team's solution they contributed to the most, what they learned from the experience, and related questions. This is done to ensure the integrity of the process and to make certain that each competitor contributed to their team's submission and to motivate all team members to participate in a way maximizing the team's quality of submission.

The assignment (only one copy per team) *and* the individual form submissions from all team members are due by 11:59 pm Eastern Standard Time (UTC-5) on **Monday, January 27, 2020** and cannot be submitted before the form is released on January 26. Teams will not be able to submit their Explorer Competition work at any later time, unless there is a short time extension publicly granted by the organizers (please do not count on that). The team member who registered the team is responsible for submitting the team's work. Please avoid sending it more than once; the last version from a team submitted before the deadline will be the submission that is graded, and any preceding one will be ignored. Teams will receive confirmation once their submission has been received within at most two days after the deadline. In the case of extraordinary circumstances or if your team members change during the week of the competition, please contact us as soon as possible at [directors@physicsu.org](mailto:directors@physicsu.org).

This assignment was brought to you thanks to the voluntary efforts by organizers and supporters of the Princeton University Physics Competition and the independently run Physics Unlimited, the non-profit organization overseeing and directing the Explorer Competition.



# Orbital resonance: building a model

## Introduction

It is a physicist's job to explain observable physical phenomena. Handwavy explanations are not science, and care must be taken to develop models that yield quantitatively acceptable results.

Though it would be nice if all physical systems admitted nice models subject to a few parameters, the world is very complex, and we must usually resort to making measured simplifications in order to actually get somewhere.

## Task

Your challenge is to develop a reasonable mathematical model for orbital resonance and to compare, after inputting any necessary parameters, its results to the known empirical data. You should then produce a scientific write-up (L<sup>A</sup>T<sub>E</sub>X) in the style of a published paper, including an abstract, a brief introduction to orbital resonance, an explanation of your model, an interpretation of its results, and a numbered list of sources. More specific details are given below.

## Steps Required for Successful Completion of the Task

**What your paper should look like** This outline explains all that we are looking for from your paper:

- a. Introduce orbital resonance.
- b. Identify two phenomena that are believed to be results of orbital resonance. These phenomena are normally observed in the Solar System, but perhaps you find some galactic phenomenon that you want to discuss.
- c. Develop a mathematical model(s) that explain these phenomena. Please don't try to use general relativity. Justify any simplifying assumptions you make, and show all work in deriving the relevant physics/math.
- d. Extract calculations from your model(s).
- e. Compare your results to the observations of the phenomena you selected and interpret them. Try to explain any discrepancies.
- f. Write up everything in a clean and presentable fashion. Figures are nice to include: we strongly encourage your work to have at least one self-created figure. (If you wish to explore ways to create high-quality figures, Inkscape is a commonly used free software for this purpose. Some physicists often use it to produce figures for their publications.)
- g. The total length of the paper is expected to be 6-12 pages. However, as teams' works will be scored relative to the others', it is the logic behind and the presentation of your model(s) that will be prioritized to length of your paper in determining the resulting ranking.

## Tips

- A simpler model is preferred to a more complex one if accuracy does not suffer appreciably.
- Feel free to look up any data you need to make the model and be sure to cite the source of this data. Also feel free to look up any relevant physics or mathematics. Crucially, do NOT plagiarize the work of others. When in doubt, cite the exact source so that the judges are fully aware of what constitutes original work and what doesn't. Failure to credit others may be grounds for the disqualification of your work, and we expect everyone to exercise good judgment: this will also be necessary in any future research work you embark upon.
- Always justify your work.

*We wish you good luck, and we hope you find this to be a valuable educational opportunity for yourselves, regardless of the results of this competition!*