Astronomy 2142: Essay Assignment, Part 1

The essay assignment is intended to bring out some of the core considerations of the *Number, Nature, Mind* GE theme. It is worth 10% of the course grade, and I have broken it into two pieces, as explained further below. This piece is due on Friday, March 21.

Background reading

Read the essay "The Unreasonable Effectiveness of Mathematics in the Natural Sciences," written in 1960 by the theoretical physicist Eugene Wigner. I have provided a pdf copy via Carmen. It is short (9 pages), but dense. There are a few paragraphs you won't be able to follow because they refer to physics or mathematics that you do not know, but you should be able to make sense of most of it. You can also ask me questions about it, and/or discuss it with your classmates.

It may also be useful to re-read pp. 84-86 of Thorne's book, giving his views on "The Nature of Physical Law."

Assignment

After reading Wigner's essay and thinking about its relation to this course, write an essay of your own with three parts:

1. *Key points of Wigner's essay*

What are the two or three main points that Wigner makes in his essay, as you understand them?

2. *Examples*

Describe two examples from this course in which mathematical reasoning was surprisingly effective in predicting phenomena in the physical world, in particular where a theory motivated by explaining some observed phenomena successfully predicted phenomena it was not "designed" to explain.

One of your examples should be drawn from Newtonian gravity, and one should be drawn from special or general relativity.

3. *Your assessment*

Do you consider the "unreasonable effectiveness" of mathematics in describing and predicting the physical world to be surprising? Why or why not? What does the success of mathematically formulated scientific theories tell us about physical reality, or human thought, or both?

Expectations

Your essay should be 3-6 pages in length, double-spaced, typed. It should be turned in *on paper* at the beginning of class on Friday, March 21. Late submissions received by Friday, March 28 will be accepted but with a half-grade deduction (e.g., B+ to B).

The essay will be graded on the quality and thoughtfulness of your ideas *and* the clarity of your writing. You should write in a way that would be comprehensible to someone who has *not* taken this class, but who might have taken a high school physics course. In particular, you should explain your examples in Part 2 completely enough that someone other than me or your classmates would be able to undertand what you've written, and you should write Part 1 for a reader who hasn't read Wigner's essay.

Second piece

After some thought, I decided to break the essay assignment for this course into two pieces, of which this is the first. You will get this essay back after I grade it. At the end of the course (last week of class), I will ask you to add examples to Part 2 based on what we learn about black holes and gravitational waves, and to revise the rest of the essay to reflect the greater expertise you have at the end of the course.

In total, the essay assignment counts for 10% of the course grade. The initial version here and the final version at the end of the course will contribute equally to that grade.

A clarification about Wigner's essay

The second paragraph of the section "Is the Success of Physical Theories Truly Surprising?" (the paragraph starting "The first example is the oft-quoted one of planetary motion") is an important one. The material in this paragraph should be familiar from section 3 of our course, but the term "second derivative" will be unfamiliar unless you have taken calculus. In the context of this paragraph, "second derivative" simply refers to acceleration, and Wigner is saying that Newton's law of gravity gives a mathematically simple formula (the inverse square law) for acceleration, not for position or velocity. (Velocity is the rate of change of position, hence a first derivative. Acceleration is the rate of change of velocity, hence a second derivative of position.)

If you just mentally substitute the word "acceleration" for "second derivative" when reading this paragraph, that will be sufficient.

FWIW, I think that Wigner isn't choosing the term "second derivative" just to be obscure. An intriguing theme in physics is that our "basic" equations are often ones that specify second derivatives, including equations in electromagnetism, quantum mechanics, and general relativity. It's not clear whether this frequent appearance of second derivatives tells us something deep about nature or is just a reflection of how physicists have gotten accustomed to formulating things.