PHYS-3202 Course Project Instructions

For the course project, you will watch the film *Gravity*, directed by Alfonso Cuarón, and answer several questions about physics topics from this class that appear in the film and about the portrayal of physics topics in popular culture from the perspective of this film. This project is worth 15% of your grade for the entire course.

General Instructions

- You can stream *Gravity* for free through the UWinnipeg library. It is the top item at this search. Click the "View Now" button and enter the username and password you use for WebAdvisor.
- Submissions **must** be typed PDF files. They should be prepared with LaTeX or else MS Word (or similar word processor) with an equation editor for mathematics (*please export your Word file to PDF to submit*). Label your filenames with your first initial, last name, and "project" (for example `AFrey_project.pdf`); if you need to break your solution into multiple parts, label them in order with page numbers (`AFrey_project1.pdf`, `AFrey_project2.pdf`, etc). See the homework submission instructions on the course outline.
- The project is due at **10:59PM Weds 15 Dec 2021**. Upload your submissions to `https://uwcloud.uwinnipeg.ca/s/wxqoYpEEa8WT2LX` . **This is the same link as for homework.**
- You may use computer software (such as python, Maple, etc) to help solve any of the questions for the project, but you **must** attach your code (or worksheet, etc) as an appendix.
- You will need to look up some information to answer some of the questions for the project. You may use any resource (such as a book or reputable web site), but you **must** cite it in your answer and include a references/bibliography section at the end. You may also make appropriate assumptions and simplifying approximations as long as you explain what them.
- **Complete each section below.** Each section is worth 25% of the project grade. Each section will be marked for thoroughness, organization, and correctness. The answer for each section should be written as an essay or lab report, using full sentences. You do not need to include every step of mathematics, but you should explain what you are doing and where any equations come from.
- The instructions below may list times in the movie in the form h:mm:ss to indicate when events happen. These times are taken from the streaming option through the UWinnipeg library.
- *Please make an appointment to discuss your project with me if you have questions or need help.* These questions are more open-ended than homework assignments.

1 Portrayal of Physics in the Film

As you watch the film, take note of how physics appears in the film, particularly any unrealistic physics or errors in physics. Some of these may overlap with aspects of physics discussed in the sections below. Write an essay describing the instances of unrealistic or erroneous physics that you noticed and how they may have been important to the plot. The film had science advisors; explain why you think the filmmakers may have decided to alter the physics for the film. Support your arguments with physics you have learned in this class. Your discussion should be qualitative, but you may make quantitative arguments if you like. This section is expected to be 250-500 words (1 to 2 pages of 12 point font with 1 inch margins).

2 Orbital Mechanics

Answer **one** of the following questions. Write your answer in essay form, including any necessary mathematics or formulae. Give quantitative answers as requested in each question.

1. From about 0:19:10 to 0:19:22, astronaut Kowalski gives some information about the orbit of the space debris that plays an important role in the film. First, is the 50,000 mile/hour debris speed realistic if the debris is in a closed orbit around the earth (compare to escape velocity)? Ignoring that issue, give some characteristics of a possible realistic orbit for the debris. It should intersect the orbits of the Hubble Space Telescope (where the movie begins) and International Space Station approximately every 90 minutes.

2. At one point, astronaut Stone is stuck in a damaged Soyuz capsule and needs to reach the Chinese Tiangong-1 space station (which was in orbit when the movie was filmed). Assume that the Soyuz is in approximately the orbit of the International Space Station. The Tiangong is in a lower orbit, and the Soyuz and Tiangong are separated by an angle of about 120° around the center of the earth. At approximately 1:10:00, Stone fires rockets on the Soyuz. Do the rockets need to fire in the same or opposite direction of Soyuz's orbit around the earth? Estimate how the rockets can change the velocity of the Soyuz capsule so that it will approach the Tiangong.

3 Accelerating Reference Frame

Answer **one** of the following questions. Write your answer in essay form, including any necessary mathematics or formulae. Give quantitative answers as requested in each question.

1. At approximately 0:32:00, astronauts Stone and Kowalksi are attached to the International Space Station by a cable. Kowalski lets go of the cable and drifts off fairly quickly. Estimate how far Kowalski is from the space station before he lets go (by measuring distances on the screen) and also how quickly he drifts away (this may be more difficult, but you can try to use perspective). Assume that he flies away due to centrifugal force because the space station is rotating. What must the angular velocity of the space station be to give an appropriate acceleration?

   (Kowalski should actually drift away due to being in a slightly different orbit than the space station, but that should only be a few meters per minute.)

2. At about 0:52:20, astronaut Stone is trying to detach a Soyuz capsule from a cable that is holding it to the International Space Station when debris hits the station. This causes the Soyuz capsule (and Stone) to start spinning around the station because it is attached to the cable (this lasts about 40 seconds). Estimate the length of the cable and speed of the Soyuz capsule's rotation around the space station. Based on that, estimate the fictitious

forces acting on the Soyuz and Stone and compare the corresponding accelerations to g (the acceleration due to gravity on earth).

4 Rotating Objects

Answer **one** of the following questions. Write your answer in essay form, including any necessary mathematics or formulae. Give quantitative answers as requested in each question.

At approximately 0:12:26, space shuttle *Explorer* is struck by space debris and begins rotating. Both questions have to do with the rotation of *Explorer* in this scene. You may model the shuttle as a triangular lamina attached to a cylinder or rectangular prism to answer your chosen question. Look up space shuttle specifications and apply them to your model to find a moment of inertia tensor you can use in your answer.

1. Estimate the angular velocity of the *Explorer* when it first starts rotating by counting rotations against the film timer (as best as is possible). Given that the debris hits the space shuttle near the end of a wing, estimate the impulse (see homework assignment 1) that the debris must impart to the wing of the *Explorer* to make it rotate that fast.

2. Assuming the *Explorer* starts rotating entirely around its long axis, use the Euler equations to find how it rotates as time passes. Specifically, does its angular velocity gain a large component around one of the other principal axes and, if so, which becomes significant first? Does the film portray the rotation of the space shuttle accurately?