# PHY151H1F FALL 2022 HW4

Prakash Shivesh

TOTAL POINTS

**24 / 24**

QUESTION 1

1 Q1 **12 / 12**

✓ **+ 4 pts marks for making reasonable assumptions and clearly communicating these assumptions**

+ **3 pts** marks for making reasonable assumptions and clearly communicating these assumptions, but also making some assumptions which were not explicitly used or needed.

+ **2 pts** marks for making any questionable or unreasonable assumptions, or for not clearly communicating an implicit assumption that was needed when solving the problem

+ **1 pts** marks for making and communicating at least one useful assumption

✓ **+ 4 pts marks for solving the physics problem to get an answer**

+ **3 pts** marks for minor mistakes when solving the physics problem to get an answer

+ **2 pts** marks for a major mistake when solving the physics problem to get an answer. A well done sketch of the situation and any other relevant representation (force diagram, velocity-time graph if not already provided, energy bar chart), gets 2 marks

+ **1 pts** marks for any reasonable progress in solving the physics problem. A well done sketch of the situation, or any other relevant representation (force diagram, velocity-time graph, energy bar chart), gets 1 mark

✓ **+ 4 pts marks for evaluating whether the answer was reasonable by comparing it with a simple solution using the given numerical values and dimensional analysis or similar arguments**

+ **3 pts** marks for evaluating whether the answer was reasonable by comparing it with an intuited estimate which was vaguely explained and based on the given numerical values

+ **2 pts** marks for evaluating whether the answer was reasonable by comparing it with a reasonable, intuited value without any justification for the intuited value

+ **1 pts** marks for evaluating whether the answer was reasonable by comparing it with an unreasonable value

+ **0 pts** marks for not evaluating whether the answer was reasonable

1 Note: Added one mark for evaluation

QUESTION 2

2 Q1contin **0 / 0**

✓ **+ 0 pts marks found for this page are included with the first page of question 1**

QUESTION 3

3 Q2 **12 / 12**

✓ **+ 6 pts marks for clearly and correctly evaluating the data with the appropriate equations and/or concepts**

+ **5 pts** marks for correctly evaluating the data with the appropriate equations and/or concepts, but missing a few minor details

+ **4 pts** marks for correctly evaluating the data with the appropriate equations and/or concepts, but missing a major detail

+ **3 pts** marks for using appropriate equations and/or concepts but incorrectly evaluating the data

+ **2 pts** marks for an attempt at analyzing the data using inappropriate equations and/or concepts which nonetheless demonstrates some understanding of relevant physics. A well done sketch of the situation and any other relevant representation (force diagram, velocity-time graph if not already provided, energy bar chart), gets 2 marks

+ **1 pts** marks for any correct statement.  A well done sketch of the situation, or any other relevant representation (force diagram, velocity-time graph if not already provided, energy bar chart), gets 1 mark

✓ + **3 pts** **marks for clearly and quantitatively answering the question based on the data**

+ **2 pts** marks for having a concluding sentence that is relevant to the question

+ **1 pts** marks for at least underlining or otherwise drawing attention to the final answer

✓ + **3 pts** **marks for correctly addressing the effect of the uncertainties on the analysis**

+ **2 pts** marks for making reasonable statements about the magnitude of the uncertainties

+ **1 pts** marks for mentioning the uncertainties in some nontrivial fashion

+ **0 pts** nothing submitted

QUESTION 4

## 4 Q2contin 0 / 0

✓ + **0 pts** **marks found for this page are included with the first page of question 2**

# PHY151 Written Homework 4

Due Nov. 27, 2022
Two questions
Please check out the rubrics on Quercus before submitting this

1. Modelling Problem: Figure skaters often make jumps that involve them spinning around the long (vertical) axis of their bodies. They start by gliding at a fairly high speed, then they dig one toe of their skate (which has spikes to help with jumps) into the ice and use that to both jump and spin. How many complete revolutions can a typical figure skater make?

Assumptions:
1. The angular velocity of a figure skater while spinning is $\omega = 15$ rad/s. Source: physics.nmu.edu
2. Air resistance is negligible, thus the angular velocity is constant while spinning.
3. A figure skater skates with the speed of $u = 36$ km/h $= 10$ m/s on ice. Source: therecord.com
4. While spinning a figure skater is assumed as a cylinder of radius $r = 0.1$ m and mass $m = 50$ kg. Source: question 12.87 from Mastering Physics.
5. The energy of the skater is conserved while jumping, this is because no force does significant work on the skater. This logic stems from the assumption that just while jumping, the displacement of the skater is negligible.
6. While making the jump, the skater jumps with an angle of 45º relative to the horizontal.

Solution:
Initial kinetic energy of skater (just before jumping) -
$KE_i = \frac{1}{2}mu^2 = \frac{1}{2} \times 50 \times 10^2 = 2500$ J
Initial rotational kinetic energy of skater (just before jumping) -
$RKE_i = 0$ J

Final kinetic energy of skater (just after jumping, spinning starts) -
$KE_f = \frac{1}{2}mv^2 = \frac{1}{2} \times 50 \times v^2 = 25v^2$ J
Final rotational kinetic energy of skater (just before jumping) -
$RKE_f = \frac{1}{2}I\omega^2 = \frac{1}{2}(50 \times 0.1^2)(15)^2 = 56$ J

From conservation of energy just before and after the jump-
$KE_i + RKE_i = KE_f + RKE_f \Rightarrow 2500 + 0 = 25v^2 + 56 \Rightarrow v = 9.8$ m/s

The time duration t, for which the skater was airborne is calculated as -
$$t = \frac{2v\sin\theta}{g} = \frac{2 \times 9.8}{9.81 \times \sqrt{2}} = 1.4 \text{ seconds}$$

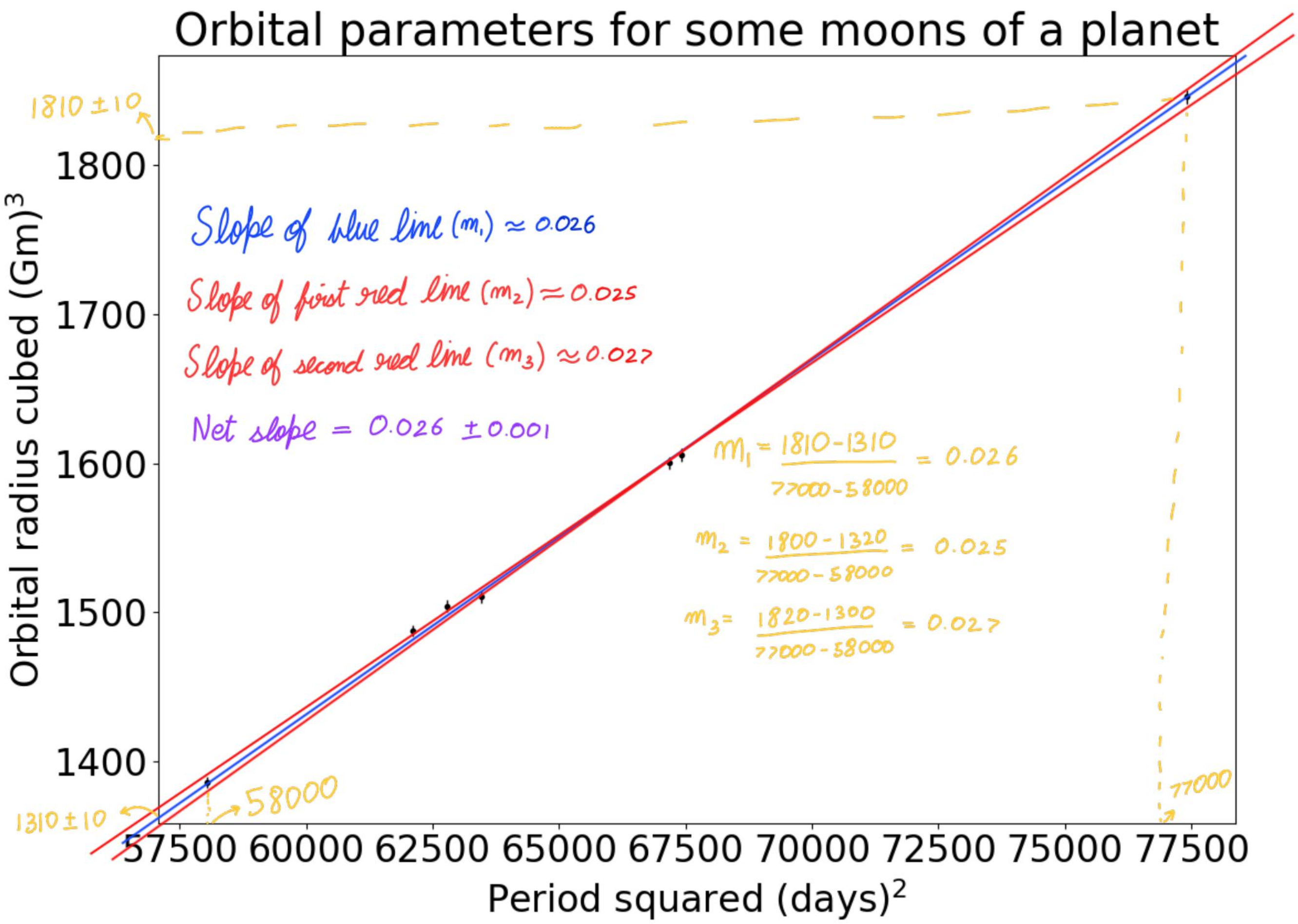
The number of revolutions completed during this time is -
$$n = \frac{\omega t}{2\pi} = 3 \times 1.4 = 4.2 \simeq 4$$

In conclusion, the figure skater completes 4 rotations in air.

Question 1 continued (if needed)

Justification:
While watching the Tokyo Olympics, I noticed that most figure skaters made 3-4 rotations while in air. My answer 4 seems about right and my assumptions for the velocities also seem appropriate. Therefore my assumption and answer are in agreement with real life scenarios.

2. Data Analysis Problem: Pictured below are the orbital paremeters for several moons orbitting the same planet. Find the mass of the planet. *Note:* Gm means gigameters, which is millions of kilometers. The Moon is about 0.384 Gm from the Earth.




Using Kepler's third law, we know that → $T^2 = \frac{4\pi^2}{GM} r^3$

Where T is time period in second, G is Universal Gravitational Constant, M is mass of planet in kg and r is orbit radius in m. By converting unit of time period to days and that of orbit radius to gigameters, we get: $(T \times 24 \times 60 \times 60)^2 = \frac{4\pi^2}{GM}(r \times 10^9)^3$. Here T is in days and r is in gigameters.

$$\rightarrow r^3 = \frac{GM \times 60^2 \times 60^2 \times 24^2 \times T^2}{4\pi^2 \times 10^{27}}$$

On a linear plot for $r^3$ vs $T^2$, slope = $\frac{GM \times 60^2 \times 60^2 \times 24^2}{4\pi^2 \times 10^{27}}$

Since G is $6.67 \times 10^{-11}$ Nm²/kg², the slope is ≈ $1.3 \times 10^{-29} \times M$

Quest 2 continued (if needed)

Linking data to relevant physics and comments on uncertainties:
The blue line represents our version of the best fit line, the red lines represent alternative best fit lines considering the error in the given data. The root cause of uncertainties in our answer is due to the error in the given data, represented by the error bars in the graph. We have accommodated uncertainties in our answer by drawing alternative (red) best fit lines passing through the error bars. By using slight approximations, a ruler and multiple best fit lines drawn to estimate uncertainties, we reached the conclusion that the slope of our best fit line is $0.026 \pm 0.001$.

Solution:
Equating the value for slope from graph with our calculated equation gives →
$1.3 \times 10^{-29} \times M = 0.026 \pm 0.001$
→ $M = 2.00 \times 10^{27} \pm 0.07 \times 10^{27} = (2.00 \pm 0.07) \times 10^{27}$

Conclusion:
The mass of planet calculated by us is completely in agreement with the data presented to us in the graph. The uncertainty which we have estimated is in accordance with the error bars shown in the graphical data. Even though we considered only some points to draw best fit lines, our value for M satisfies most other points too, verified by plotting the exact graph equation on Desmos Virtual Graphing Calculator. In real life the mass of Jupiter is expected to be around $1.9 \times 10^{27}$ kg, which has multiple moons around 10-15 Gm. Therefore our value for M is close enough to real values too.