Jupiter Lab Guide Experiment A08

Part A: Comparison of Storms on Jupiter and Earth

The first thing you have to do here is on page 3; you assume that the Great Red Spot (GRS) is an ellipse, and you are going to find the semi-major and semi-minor axes of this ellipse by comparing it to the Earth. Then, you'll find the circumference of this ellipse using the equation given to you in the manual.

A.) **(2 points) SEMI-MAJOR AXIS (a)**: in the picture above this question in the manual, we can consider the point where the two Earths touch as being the center of the ellipse. We want the semi-major axis of this ellipse in terms of the size of the Earth (the Earth is to scale here, and the semi-MAJOR axis is the radius of the ellipse associated with its WIDEST diameter; see the image below). We see that it's a bit longer than one whole Earth (i.e., one Earth diameter), but not quite 1.5 Earth diameters. So, as an approximation, we can say that the semi-major axis is 1.25 times the Earths diameter:

$$a = 1.25 \times D_{Earth} = 1.25 \times (12{,}742\ km)$$

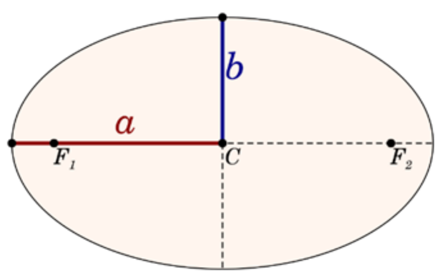
Where the Earth's diameter is given to you in the problem.

B.) **(2 points) SEMI-MINOR AXIS (b):** Now let's imagine putting one of the Earths right on top of the center point. We would then see that the semi-MINOR axis (i.e., the radius associated with the SMALLEST diameter of the ellipse) would be just a little pit longer that the Earths RADIUS (NOT its diameter here, see that b in the diagram below would look to be just a little bit longer than half of the Earths RADIUS if its centered at the middle). So, as an approximation, we can say that the semi-minor axis is roughly 1.25 times the Earths radius – which itself is half the diameter.

$$b = 1.25 \times R_{Earth} = 1.25 \times \frac{D_{Earth}}{2} = \frac{a}{2}$$

So, the idea we should get out of this is that the semi-major axis is about TWICE the size of the semi-minor axis.

C.) **(2 points) CIRCUMFERENCE:** Here we just need to plug in a and b right into the definition for C – just do not forget the 2π out front!

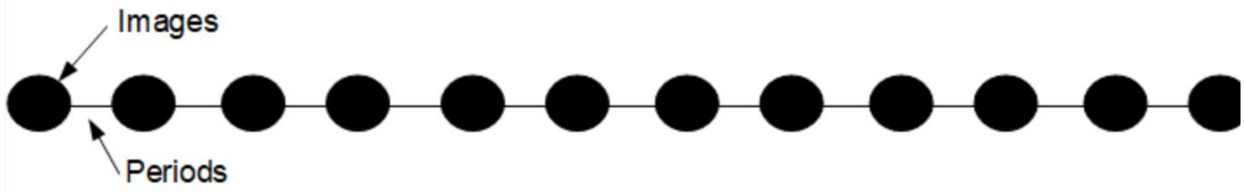


$$C \approx 2\pi \sqrt{\frac{a^2 + b^2}{2}}$$

On page 4 we have 12 images of Jupiter taken by the Voyager 1 spacecraft in 1979. As the spacecraft is moving towards the planet, the planet itself is rotating. Thus, in order to get these images of the great red spot, Voyager had to take one picture every time the planet rotated back around – i.e., one picture every JUPITER day (which is NOT equal to one Earth day!) In every one of these images a specific part of the GRS is marked by an X – how this X moves over the course of these 12 Jupiter days will tell us how fast the storm is moving.

1.) **(4 points)** While Voyager was taking an image of Jupiter every JUPITER day (as to get the same part of the planet in each image), the spacecraft was doing so for a total amount of time equal to **28 Earth days.** These 12 images are just a bunch taken from the total **60 images** shot during this time frame. Thus, we can find approximately how many hours pass between images by taking the total number of hours (28 x 24) divided by the number of shots taken (60).

2.) **(4 points)** We found how many hours pass between shots before, so now we can easily find how many hours are covered over this range of 12 images above. Does this mean we can just multiply what we got in the previous question by 12 (the number of images)? NO! We need to consider something important – the



time we found was the time period BETWEEN images. In this set of 12 images, how many of these periods do we have? From the image below we can see that we actually have only 11 periods. Thus, we need to multiply the time per period (found in the previous question) by the number of full periods (11).

3.) **(6 points)** Notice that the special part about the 12 images given to you is that the X in the GRS makes one full rotation – so the time over which these images were taken (found in the previous question) would be the time it takes for the GRS to rotate once. This, combined with a distance over which this X has traveled, is enough for us to determine the **velocity** of this point – i.e., the velocity of the outer part of the GRS. WE know that velocity is just the distance traveled divided by the time it took to travel that distance, so using the circumference you found at the start of this section and the time you found in the previous question, find:

$$v = \frac{distance(\mathrm{km})}{time(\mathrm{hr})} = \frac{Circumference}{Time\ over\ 12\ images}$$

4.) **(5 points)** The rotation *period* is just how long it takes for the X to make one full rotation. You technically found this already in question 2, but now go ahead and find how many EARTH days this is.

Part B: Comparison to One of the Strongest Cyclones on Earth

The GRS on Jupiter is just like any storm on Earth except much, much larger (as we saw in the previous section). In this section we are going to compare it to some of the strongest storms we know of here on Earth.

1.) **(10 points)** In the previous section, we found the *velocity* of the outer part of the GR – this gives us a good estimate of the wind speeds of this storm. Here we want to know how much faster these wind speeds on Jupiter are than those of our strongest storms here on Earth. We can do that by finding a ratio.

$$Ratio = \frac{Wind\ speeds\ on\ Jupiter\ (^{km}/_{hr})}{Wind\ speeds\ on\ Earth\ (^{km}/_{hr})}$$

The discussion above this question in your lab manual discusses how a cyclone in 1991 had landfall windspeeds of 258 km/hr – this is what you will compare to the value you found in part A. Since we have the wind speeds of Jupiter in the numerator of this ratio, this ratio will tell us how many times larger (or smaller depending on your calculations) the wind speeds on Jupiter are compared to Earth. For example, if your ratio is found to be 2, then this would mean that the wind speeds found on Jupiter are **2 times** the wind speeds found on Earth.

2.) **(10 points)** You are essentially looking for the *percent difference* between the velocity YOU calculated in part A and that measured by scientists (610 km/hr). As a reminder:

$$Percent\ Difference\ (\%) = \left|\frac{Accepted\ Value\ -\ Calculated\ Value}{Accepted\ Value}\right| \times 100$$

3.) **(5 points)** Think a little here, what could be your main source of error? Hint: how exact was our circumference calculation?

Part C: Galilean Moons

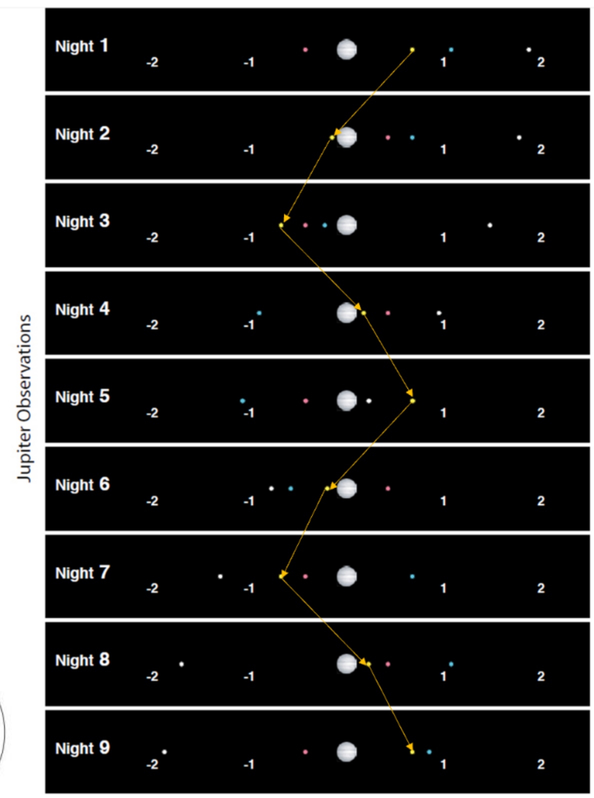
The 4 Galilean moons of Jupiter that we will look at in this section have one important characteristic - they pretty much all revolve around Jupiter in the same *plane*. This means that when we observe them from Earth, we only see them edge-on – they look like they are moving in straight lines across the sky rather than the circular orbits we know they are traveling. Galileo would have seen something just like this when peering at the planet through his telescope. With the knowledge that the moons are ACTUALLY orbiting in circles, we can determine their orbital periods. In this lab guide we will look at one of the moons in particular, find its orbital period from "observations," and then determine the identity of that moon. Note that the lab manual refers to a transparency sheet – you can use any kind of plastic of some sort if you would like, or just doodle right on the picture itself.

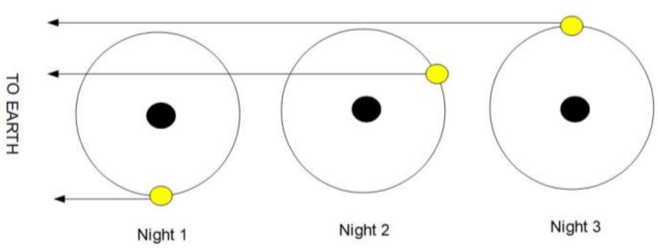
1.) The moon we will pick in our example is the yellow dot (see the image below). See that each image (row) represents a picture of Jupiter and its moons on a specific night.

2.) **(10 points)** You can see in the image that I went ahead and connected each of the yellow dots (representing the location of a certain moon every night). We can clearly see that there is a clear back-and-forth pattern as we go form night 1 to night 9.

3.) You can do this with all the other moons and see a similar behavior.

4.) **(4 points)** Here is a tricky part. As we are seeing them, the moons look to be moving back and forth in straight lines. However, we KNOW that they are actually moving in *circular orbits*; we are just looking at those orbits form the side! So, we need to imagine what these pictures look like from above:





In the diagram above, we are going to take a look at the first three days. We are observing the system from Earth located far to the left. By looking at all 9 nights, we can see that on nights 1, 5 and 9 the yellow dot (moon) is the farthest to the right as it goes – so this would mean that this location corresponds to the "bottom" of our circular orbit in our diagram. Then, as we go forward one night, the moon has continued on its counterclockwise orbit into a location that APPEARS TO US as being on the other side of Jupiter, but we know that it really is just at another point along its circular orbit. On the third night, and similar to the seventh night, the moon reaches its left-most point – meaning we are at the "top" of our circular orbit in our diagram. Over these three nights, we see that the moon has gone only one HALF of its full orbit. We see that when the yellow dot returns to its starting point (i.e., its points from night 1), it has then traveled one full orbit around Jupiter! This happens on night 5. Does this mean our orbital period (the time it takes to make one orbit around Jupiter) is 5 days? **NO**, similar to part A we have to measure *full days*; if we start from night one and go to night two, *one full day has* *passed*. Thus, going from night one to night 5 means that *four full days have passed* – the yellow moons orbital period is 4 days! You can now figure out the periods of the remaining 3 moons.

5.) **(4 points)** You will be using the first image in part C of the lab manual to answer this one. Remember how in the previous question we found that all 4 moons extended right-and-left a certain distance, each a different amount. We can also see in the image that each moon has a different orbital radius (the distance from it to Jupiter in the center). You can match the moon with the largest orbital radius (the one corresponding to the largest circle) with the one that extends the farthest right-or-left! Using this logic, you can then determine the identity of the other 3 moons.

6.) **(4 points)** The question is telling you that the blue moon extends right-or-left to only +1/-1. By now you should realize that these maximum extension points for each moon correspond to the orbital radius of the moon (since we are assuming the orbits are circular and the distance from each moon to Jupiter always stays the same throughout the orbits). This question is easy; on night 1 the blue moon looks to be really close to the (+1) measurement, and since the question says this is about 665,000 miles, this is how far away the moon is.

7.) **(3 points)** This can be considered a trick question – what did we just say about the *orbital radius of every moon*? Does it change? What did we find was the distance form the blue moon to Jupiter in the previous question? Does this distance change as the moon moves along its *circular* orbit?

Part D: Mass of Jupiter

We will be using a special form of Kepler's third law in order to find the mass of the planet Jupiter just by observing the orbital period and radius of one of its moons (any one of them – it's your choice which one). The equation we will be using is the following:

$$\boxed{P^2 = \frac{4\pi^2}{GM}a^3}$$

1.) **(15 points)** You will need to choose one of the moons form part C and find its orbital period (P) and orbital radius (a). Remember, you found the orbital period *in days* by looking at how long it took the moon to come back to the same location over the course of multiple nights, and you found the orbital radius *in miles* by realizing from question 6 that the distance between the numbers in the image is around 665,000 miles. HOWEVER, you need to convers the orbital radius **from miles to meters** and the orbital period **from days to seconds**! This is *very* important to get the correct answer in kilograms. Note that the gravitational constant (G) is given to you in the manual. Plug in all these values in correctly above, solve for M, and you'll get a reasonable answer for the mass of Jupiter!

2.) **(10 points)** Using *your value* for the mass of Jupiter found in question 1 and the *actual value* for the mass of Jupiter (1.898×10^{27} kg), you need to find the percent difference between the two. If you converted your values correctly, you should get a value for mass that is pretty close to the actual mass, resulting in a small percent difference.