Some useful equations:

\[ P^2 \propto a^3 \quad F = ma \quad P^2 = \frac{4\pi^2}{G(M+m)}a^3 \quad F = \frac{GMm}{r^2} \]

1. **(10 points)** During which two phases of the lunar cycle are tides strongest (ie. high tides are higher than usual and low tides are lower than usual)? Draw a diagram of one of these lunar phases, **labelling each object and the lunar phase you are drawing.**

2. **(10 points)** Write down the formula for the acceleration due to gravity (g) you feel standing on the surface of the Earth in terms of any of the following constants you think you need: \( G, M_{Earth}, M_{me}, M_{Sun}, M_{Moon}, R_{Earth}, R_{Moon}, R_{Earth-to-Sun}, R_{Earth-to-Moon}. \)
3. **(10 points)** Which of Kepler’s laws enables us to use observations of Charon to calculate the mass of Pluto? Explain your answer: what properties of Charon’s orbit do you need to observe? (Recall that the mass of Charon is much smaller than the mass of Pluto)

4. **(8 points)** For each of the following, write down which planet is being described (each planet will match ONE fact).

- This planet is occasionally obscured by global dust storms.
- The tidal forces of this planet are responsible for the extreme volcanism on Io.
- This planet’s rotation axis is extremely tilted with respect to its orbital axis.
- This planet’s thick atmosphere creates a runaway greenhouse effect.
- This is the only planet with plate tectonics.
- The density of this planet is low enough that it would float in water if you could find a bathtub big enough!
- Due to the tidal forces of the Sun, this planet’s rotation period is exactly \( \frac{2}{3} \) of its orbital period.
- Before this planet was observed, its presence was predicted by careful analysis of the orbits of the other planets.

5. **(2 points)** Which two elements are the Jovian planets made up of (mostly)?