COIS 1400H Assignment 2 Question 2

Punyaja Mishra

0660001

Assume you are given the task of calculating the weight of the moon.
The key for this question is to be aware of basic assumptions and where errors might be introduced into the model. You can be creative for the question if you like.

a) Describe which values you need and what error might be associated with measuring the values of those variables (2 marks).

We can calculate the weight of the moon by using the Newton's Law of Gravitation.

$F = G*M*m/r^2$

F – centripetal force between Earth & Moon

G – Gravitational Constant

M – Mass of Earth

M – Mass of Moon

R – Distance between the centre of mass of Earth & Moon

The values required for this calculation are as follows:

1. **Gravitational Constant**
2. **Earth's Mass**

We need the mass & weight of any object on Earth and the Earth's Radius to calculate the Earth's Mass. We use the same formula as above where F is the weight of the object. The weight of the object is calculated by the formula W=m*g, where m is the mass of the object and g is the gravitational acceleration on Earth that it is facing

3. **An object on Earth, its mass and weight**
4. **Gravitational Acceleration of Earth**
5. **Radius of Earth**

The distance between Earth & Moon is the 'r' in our formula

6. **Distance between Earth & Moon**

F is the centripetal force between Earth Moon which can be calculated using the formula

Mv/r^2, where 'v' is the speed of Moon

7. **Centripetal Force between Earth & Moon**
8. **Speed of Moon**
9. **Radius of Moon**

Once we have our 'm', the mass of the Moon, we can use the W=m*g formula, where m is the calculation we just did & g is the gravitational acceleration of the moon

10. **Gravitational acceleration of Moon**

There are a lot of assumptions and calculations involved in this entire process and therefore all the variables have some error associated with them.

1. Gravitational Constant – is a constant and constants always have error of approximations/assumptions associated with them.

2. Earth's Mass/ Weight of the object on Earth/ gravitational acceleration = Calculation of Earth's Mass is dependent of weight of an object on Earth, and weight of the object is again dependent on a constant $g=9.8m/s^2$, the gravitational acceleration of Earth and we know constant have some amount of error in them. The error may be in the precision to decimal places of the values
   Also, if we dig deeper into physics (quite unreasonable point here), we are also excluding the negligible force that the object is exerting on Earth (because the Earth's force is way more than this force by the object), but this assumptions does lead up to precision error maybe to the 20^{th} decimal place.

3. Centripetal Force between the Earth and Moon – Centripetal force comes with an assumption of a circular orbit, but we very well know that moon does not have a circular but an elliptical orbit.
   Also, external factors like the Gravitational Force of Sun acting on BOTH Earth & Moon are not being considered and that also leads up to error in the precision and correctness of the value

4. Distance between Earth & Moon – We assume that the mass/ centre of mass of the two bodies lies at the very centre of them and therefore there is an error in this distance between them

The way we calculate the earth's Mass, can also be done for calculation of Moon's Mass. However we need to go to the moon for that :)

b) Research online how at least one of the values are measured and describe the method in your own words (1 mark)

Describing the method of how Earth's Mass is calculated

Requirements: An object on Earth

Method:

1. Take the object on Earth, and measure its Mass. This will be stored as the variable 'm'
2. Now multiply the mass of the object with the gravitational acceleration on Earth g = 9.8 m/s^2 , this gives us the Weight of the object, which is the force acting between the object and the mass. This will be our variable F
3. The radius of the Earth will be r
4. Gravitational Constant G is $6.67408*10^{-11}$ m^3 kg^{-1} s^{-2}
5. Now putting all these values into the formula $\mathbf{F = G*M*m/r^2}$

We are calculating the value of M in this formula and that would be the Earth's Mass

(Part c next page)

c) estimate the overall error you might have after calculating the weight from your variable's values (2 marks).

$$\mathbf{F = G*M*m/r^2}$$
$$\mathbf{m = F*r^2 / G * M}$$
$$\mathbf{W =}$$

Considering all the values and errors associated with these values of our variables, the calculation goes as follows –

Earth's Mass **M** = $(\text{Weight}_{\text{object}} * \text{Radius}_{\text{Earth}}) / G*\text{Mass}_{\text{object}}$

- Errors in Variables:
  - Error in g=9.8 can be + - 0.1
  - Error in weight of object = + - 0.1
  - Error/uncertainty in G = $2.2*10^{-5}$ ms^{-2}
- Total Error: $0.004545 * 10^5$

Distance between Earth & Moon **r**

- Error = 1.25 km

Force between Earth & Moon = $20.27 * 10^{19}$ N

- Assuming error by 10^{-5} same as Gravitational constant since the force is gravitational force between them

Error associated with Mass of Moon = 10^5 approximately

Error with gravitational acceleration of moon +- 0.1

Overall error = $0.1 * 10^5$ probably…

References

References were used for getting values of errors and uncertainties of the constant values

1. Distance between Earth & Moon
   Wikipedia contributors. (2022, March 1). *Lunar distance (astronomy)*. Wikipedia. https://en.wikipedia.org/wiki/Lunar_distance_(astronomy)#:%7E:text=From%20the%20measurements%2C%20the%20distance,1.25%20km%20(0.777%20mi).

2. Gravitational Constant G
   Wikipedia contributors. (2022a, February 25). *Gravitational constant*. Wikipedia. https://en.wikipedia.org/wiki/Gravitational_constant#:%7E:text=constant%20of%20gravitation%3A,Value%20and%20uncertainty,compared%20to%20other%20fundamental%20forces.&text=This%20corresponds%20to%20a%20relative,%E2%88%925%20(22%20ppm).

3. Gravitational acceleration g
   https://www.nhn.ou.edu/~johnson/Education/Juniorlab/Error-SigFig/SigFiginError-043.pdf