7.1.5 e3 Universal Law of Gravitation Narrative

Time: 45 minutes	**Anchor Phenomena:** An astronaut is able to jump many feet on the moon even though he is wearing a very heavy spacesuit.
Big Idea: Gravitational pull between objects depends on the mass of the two objects.	
CCCs System and system models Constructing Explanations	**Practices** **Engaging in argument from evidence** **Using mathematics and computational thinking**

EPISODE SNAPSHOT: Students **engage in argument** how changing the mass of an object or changing the distance between two objects affects the gravitational force.

GATHER

Tell students they will be exploring how the gravitational pull between objects in a system depends on the mass of the two objects today. Newton not only explained the three laws of motion, but he explained how the force of gravity works, not only here on Earth, but also in space. His theory about gravity is called the Universal Law of Gravitation. Have students go to the "Gravity Force Lab" PHet simulation. Have them fill out the observation/research portion of their handout as they learn how the simulation works. Discuss their findings before continuing.

Research/Observations

How does changing the distance between the objects in the system affect the force between them?	Making the distance bigger makes the force smaller and making the distance closer makes the force larger.
What happens to the force between the objects in the system when "Mass 1" is increased?	The force increases when the mass increases.
What happens to the force between the objects in the system if "Mass 2" decreases?	The force decreases with the mass decreases.
In which direction are the gravitational forces acting on the objects in the system?	The forces are always toward each other, attractive forces.
What are the three things you can change in this experiment?	Mass 1, Mass 2, and the distance between the objects. Force does change, but you cannot change the force. The force is the result of changing one of the three things mentioned above.

Have the students determine the three things that they can directly changed by them this system (Mass 1, Mass 2, the distance between the masses). They will be selecting two of these to be an independent variable later. Help them determine what the dependent variable will be (the gravitational force between the objects). Have them select their first independent variable, the mass of one of the objects. The mass of the other object and the distance between the objects must remain constant. Have the students collect data about the gravitational force as they change the mass. Then have them switch independent variables and change the distance while the mass of the two objects remains constant. Students collect data on how the gravitational pull changes with distance.

REASON

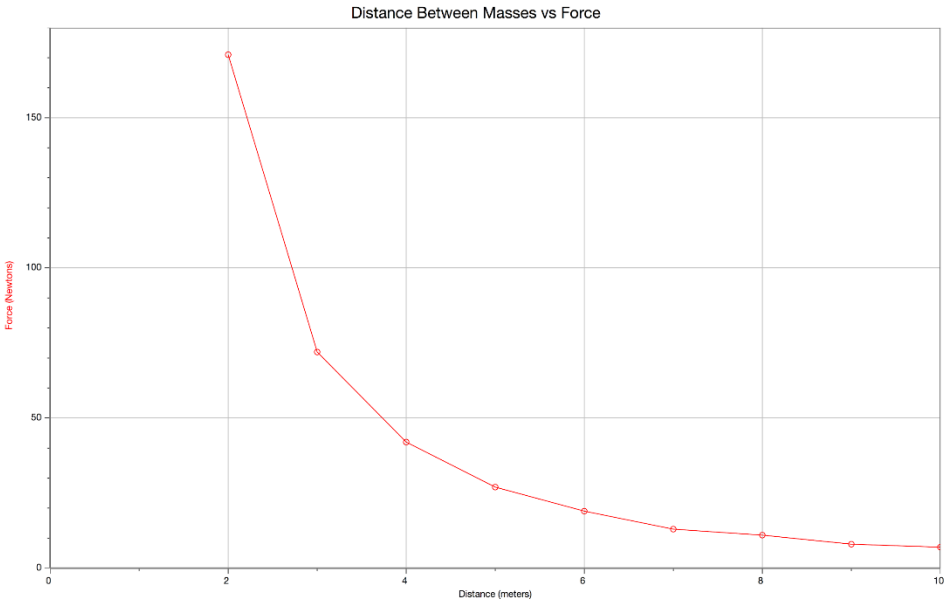
The students will **use mathematics and computational thinking** as they graph the data they collected and then explain the trends they see in the graphs. They should see that the graph of mass and gravitational force has an upward trend and that gravitational pull increases as the mass of an object increases. The graph of distance and gravitational force should have a downward trend showing that gravitational pull decreases as distance increases.

Teacher Note: Below are data tables and graphs compiled using the Phet simulation:

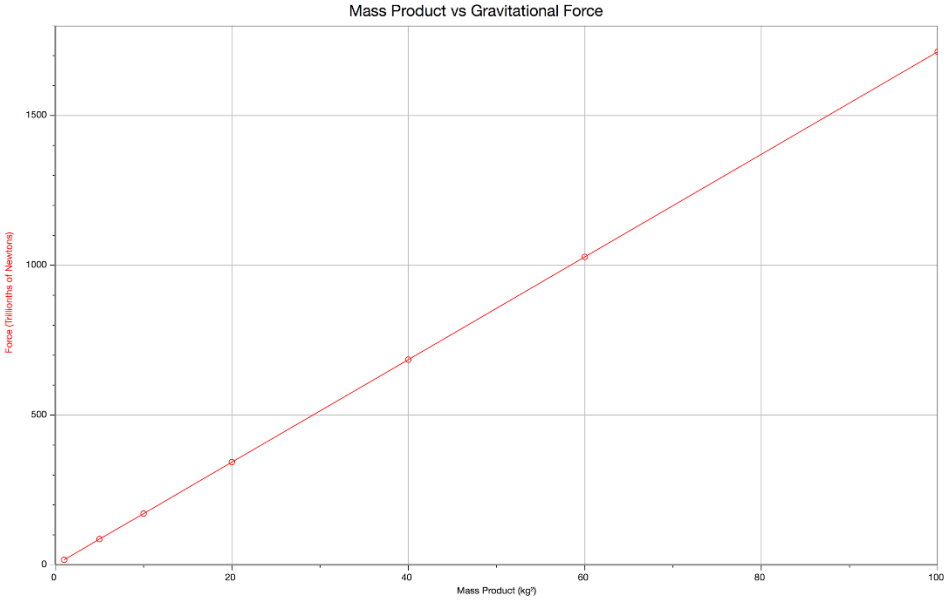
m1 was set to 10.0 kg and m2 was set to 1.0 kg and the force is actually (x 10^{-12} Newtons)

m1 was varied but m2 was constant at 1.0 kg, the distance was constant 2.0 m

Distance vs Force	
Distance (meters)	Force (Newtons)
2	171
3	72
4	42
5	27
6	19
7	13
8	11
9	8
10	7



Mass Product vs	
Mass (kg^2)	Force (Trillionths
1	17
5	86
10	171
20	343
40	685
60	1028
100	1713



COMMUNICATE

Students write a conclusion, summarizing the Universal Law of Gravitation and engaging in argument from evidence by citing data from their experiment.

Assessment: The conclusion is the assessment for this activity. Proficient students should be able to summarize the universal law of gravitation. Two objects in a system are attracted to each other. The greater the mass of an object, the stronger the gravitational pull. The greater the distance between the objects, the weaker the gravitational pull. They should also give evidence for this claim from their experiment.	**Materials, resources, handouts, etc:** ● "Gravity Force Lab" PHet simulation, https://phet.colorado.edu/sims/html/gravity-force-lab/latest/gravity-force-lab_en.html ● 7.1.5 e3 UniversalLawGravitation