Newton's Law of Universal Gravitation
Lesson Notes

Learning Outcomes
- What is the conceptual meaning of Newton's Law of Universal Gravitation?
- How is the Law of Universal Gravitation used to solve Physics word problems?

Universal Gravitation Relationships
- The force of gravitational attraction (**F_{grav}**) between any two objects is inversely proportional to the square of the distance (**d^2**) between the objects' centers.

  $F_{grav} \sim 1/d^2$
- The force of gravitational attraction (**F_{grav}**) between any two objects is directly proportional to the product of the masses (**$M_1 \cdot M_2$**) of the two attracting objects.

  $F_{grav} \sim M_1 \cdot M_2$

$$F_{grav} \sim \frac{M_1 \cdot M_2}{d^2}$$

Thinking Proportionally - Distance
By whatever factor the **separation distance** is changed, the **F_{grav}** value is changed in the *opposite direction* by the square of that factor.

Double separation distance ⇒ F_{grav} becomes 1/4-th the original value.

Triple separation distance ⇒ F_{grav} becomes 1/9-th the original value.

Halve separation distance ⇒ F_{grav} becomes 4 times the original value.

And from Newton's Apple and the Moon argument:

60X separation distance ⇒ F_{grav} becomes 1/3600-th the original value.

Thinking Proportionally - Mass
By whatever factor either **mass** is changed, the **F_{grav}** value is changed by the same factor. If both **mass** values are changed, then two changed must be made to the **F_{grav}**.

Double M_1 ⇒ F_{grav} becomes 2X the original value.

Triple M_2 ⇒ F_{grav} becomes 3X the original value.

Double M_1 and Triple M_2 ⇒ F_{grav} becomes 6X the original value.

Halve M_1 ⇒ F_{grav} becomes ½ the original value.

Halve M_1 and Triple M_2 ⇒ F_{grav} becomes 1.5X the original value.

Universal Gravitation Constant

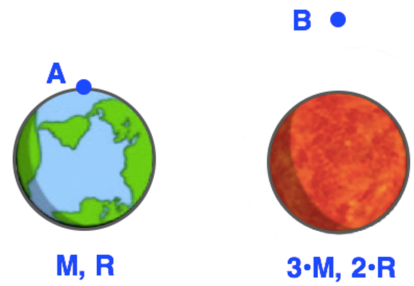
Newton's Law of Universal Gravitation is a proportionality statement with no known value for the proportionality constant. The proportionality constant - known as the **Universal Gravitation Constant** was determined years later.

$$F_{grav} = G \cdot M_1 \cdot M_2 / d^2 \quad \text{where} \quad G = 6.6743 \times 10^{-11}\ N \cdot m^2/kg^2$$

Show your solution to the four example Problems (Slides 6, 8, 9, and 10)

Example Problem 1 - Thinking Proportionally

Two objects – A and B - having the same mass are located in a different set of gravitational conditions. The relative planet mass (expressed in terms of M) and the relative distance of each location from the planet's center (expressed in terms of R) are shown. The gravitational force is greatest at location _______ … by a factor of ________.



Example Problem 2 - The Sun and the Earth

Determine the force of gravitational attraction between the Sun (M_{Sun}=1.989×10^{30} kg) and the Earth as you stand on its surface (M_{earth}= 5.972×10^{24} kg, $d_{Sun-Earth}$= 1.496×10^{11} m).

Example Problem 3 - You and the Earth

Determine the force of gravitational attraction between you (M_{You}=75 kg) and the Earth as you stand on its surface (M_{earth}= 5.972×10^{24} kg, R_{earth}= 6.3781×10^6 m).

Example Problem 4 - You and Your Lab Partner

Determine the force of gravitational attraction between you (M_{You}=75 kg) and your lab partner ($M_{Partner}$=62 kg) when sitting in your seats, spaced 1.2 meters apart (measured from their centers).