Name ______________________________

Planetary Motion & Gravitation (p. 171 – 178)

I. Planetary Motion & Gravitation

p. 171 - 172

1. **Who were the two pioneers that disproved the geocentric model of the solar system?**

    1. Nicholas Copernicus (1543) - (developed heliocentric model) (1473 - 1543)
    2. Tycho Brahe (1560) - (witnessed supernova in 1572; observed planets extensively for 20 yrs.) (1546 - 1601) - (lost part of his nose in fight)

II. Kepler's Laws

Kepler
- Brahe's assistant
- Studied Brahe's work + used his instruments
- Discovered elliptical path of planets

1. (1571 - 1630) **Johannes Kepler believed that geometry and mathematics could be used to explain what about the planets?**

    1. Number of Planets 2. Distance to planets 3. Motion of Planets

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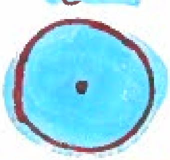
2. **State Kepler's First Law.**

    - The paths of planets are ellipses, with the Sun at one focus.

3. **Define the term ellipse.**

    Ellipse – an oval shape, which may be elongated or nearly circular

$e = 0$

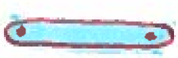


Perfect Circle

4. **How are comets examples of ellipses?**

    Short-period + Long-period comets vary according to ellipse shape.
    (Kuiper Belt) (Oort Cloud)

$e = 0.999$



Close To Straight Line

5. **State Kepler's Second Law.**

    - An imaginary line from the Sun to a planet sweeps out equal areas in equal time intervals (p. 173 Top)
    (Closest = Perihelion; Farthest = Aphelion)

6. **State Kepler's Third Law.**

    - The square of the ratio of the periods of any two planets revolving around the Sun is equal to the cube of the ratio of their average distances from the Sun.

7. **Write out the formula to determine Kepler's Third Law of planetary motion.**

Planet Periods = T_A, T_B

Average Distances = r_A, r_B

$$\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$$

$r_E = 6.4 \times 10^6$ meters

↑ (radius Earth)

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III. Newton's Law Of Universal Gravitation

1. Identify the relationship Newton discovered between force and distance of planets.

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$F \alpha \frac{1}{r^2}$ (r = distance between centers of planet + Sun) (inverse relationship)

↑ proportionate

2. Define the term gravitational force.

Gravitational Force – force of attraction between two objects that is proportional to the objects masses

$F_g \propto G(m_1 m_2)$

3. State Newton's Law Of Universal Gravitation.

I am attracted to everyone!

- Objects attract other objects with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them

4. Write out the formula to determine Newton's Law Of Universal Gravitation.

(*) $F = G\frac{m_1 m_2}{r^2}$ $G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$ → gravitational constant

IV. Universal Gravitation & Kepler's Third Law

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1. Derive the period of a planet orbiting the Sun by combining Newton's and Kepler's Laws.

1. Restate Newton's Second Law in terms of planetary mass and centripetal acceleration.

$$F_{net} = ma = m_p a_c$$

2. Restate $F_{net} = m_p a_c$ using $a_c = 4\pi^2 r/T^2$.

$$a_c = 4\pi^2 r/T^2 = F_{net} = \frac{m_p 4\pi^2 r}{T^2}$$

3. Equal the above equation to the Law Of Universal Gravitation to get planetary period.

(*)
$$\frac{m_p 4\pi^2 r}{T^2} = G\frac{m_s m_p}{r^2} = T = \sqrt{\left(\frac{4\pi^2}{G m_s}\right) r^3}$$

4. Write out the formula to determine the period of a planet orbiting the Sun.

(*)
$$T = 2\pi\sqrt{\frac{r^3}{G m_s}}$$

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V. Measuring The Universal Gravitational Constant

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1. **Who developed equipment to measure gravitational attraction between objects?**

   Henry Cavendish

2. **In general, how did Cavendish determine the value of G?**

   - Two large + two small spheres suspended from a wire on a rod

   (Attraction of small spheres to larger spheres measured using angle of reflection)

3. **Experimentally, what did Cavendish determine for the value of G?**

   $G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$

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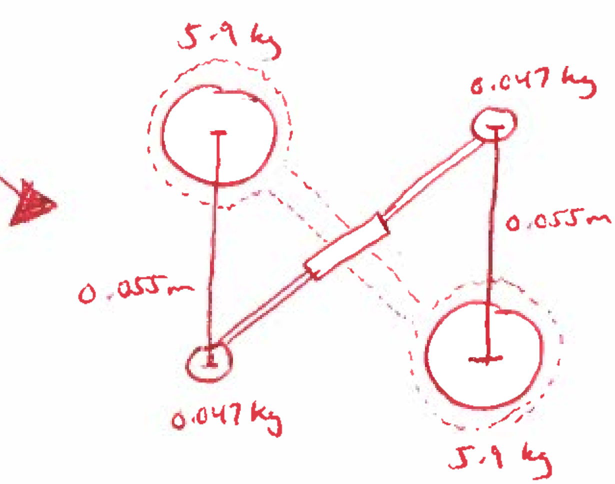
4. **What were two consequences of Cavendish determining the value of G?** "Weighing Earth Experiment"

   1. Determined mass of Earth + Sun
   2. Ability to calculate gravitational force between two objects

5. **Rearrange the equation for the Law Of Universal Gravitation ($F_g = G((m_1 m_2)/r^2)$ and Newton's Second Law Of Motion ($F_g = mg$) to solve for the mass of Earth.**

$$F_g = G\frac{m_E m}{r_E^2} = mg; \qquad g = G\frac{m_E}{r_E^2} \qquad m_E = \frac{g r_E^2}{G}$$



$$F = G\frac{m_L m_S}{r^2} = (6.67\times10^{-11}\ N\cdot m^2/kg^2)\left(\frac{(5.9\ kg)(4.7\times10^{-2}\ kg)}{(5.5\times10^{-2}\ m)^2}\right)$$

$$= 6.1\times10^{-9}\ N$$