Universal Gravitation & the Inverse Square Law

Universal Gravitation Worksheet #1

1. The evidence that stimulated Newton to propose the law of universal gravitation emerged from a study of
   a. the motion of the moon and other celestial or heavenly bodies
   b. the fall of an apple to the Earth
   c. the gravitational interaction of smaller objects upon the Earth
   d. nonsense! There was no evidence; it was just proposed as a theory.

2. The universal of Newton's law of universal gravitation is a common source of confusion. The universal means that
   a. the amount of gravitational forces is the same for all objects.
   b. the acceleration caused by gravity is the same for all objects.
   c. the force of gravity acts between all objects - not just between the Earth and an object, but also between two people. All objects with mass attract.

3. According to Newton's gravitation law, the force of gravitational attraction between a planet and an object located upon the planet's surface depends upon ____. Choose all that apply.
   a. the radius of the planet
   b. the mass of the planet
   c. the mass of the object
   d. the volume of the object
   e. nonsense! None of these variables affect the force of gravity.

4. The more massive that an object is, the ______ (more, less) that the object will be attracted to Earth.

5. The more massive the Earth is, the ______ (more, less) that another object will be attracted to Earth.

6. The greater that Earth's radius is, the ______ (more, less) that another object will be attracted to Earth.

7. In the mathematical form of Newton's law of universal gravitation (see equation at right), the symbol G stands for ______.
   a. gravity
   b. the acceleration of gravity
   c. the gravitational constant

8. TRUE or FALSE: The value of G (in the equation above) is an enormously large number; that explains why (at least in part) the force of gravitational attraction between the Sun and the very distant Earth is such a large number.

9. TRUE or FALSE: Two lab partners attract each other with a gravitational force. However, it is impossible to calculate such a force since it is only an unproven theory.

10. TRUE or FALSE: The notion that any two objects attract each other gravitationally is a theory. There is no empirical evidence for such a notion.

11. Orbiting astronauts on the space shuttle do not have weight in space because
   a. there is no gravity in space
   b. there is no air resistance in space
   c. there are no scales in space
   d. the food is terrible and they work all the time
   e. nonsense! The astronauts do have weight in space.
12. Use the gravitational force equation to fill in the following table \((G = 6.673 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2)\).

<table>
<thead>
<tr>
<th>Mass of Object 1 (kg)</th>
<th>Mass of Object 2 (kg)</th>
<th>Distance of Separation* (m)</th>
<th>(F_{\text{grav}}) (N)</th>
<th>Significance of Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>60.0</td>
<td>60.0</td>
<td>1.0</td>
<td>(2.4 \times 10^{-7})</td>
<td>Two typical students in physics class</td>
</tr>
<tr>
<td>60.0</td>
<td>5.98 \times 10^{24}</td>
<td>6.37 \times 10^6</td>
<td>590</td>
<td>A typical student on the surface of the Earth</td>
</tr>
<tr>
<td>60.0</td>
<td>11.96 \times 10^{24}</td>
<td>6.37 \times 10^6</td>
<td>1180</td>
<td>A typical student on a planet with twice the mass of Earth</td>
</tr>
<tr>
<td>60.0</td>
<td>5.98 \times 10^{24}</td>
<td>3.18 \times 10^6</td>
<td>2368</td>
<td>A typical student on a planet with half the radius of Earth</td>
</tr>
<tr>
<td>60.0</td>
<td>5.98 \times 10^{24}</td>
<td>6.47 \times 10^6</td>
<td>572</td>
<td>A typical student in orbit 60 miles above the Earth</td>
</tr>
<tr>
<td>60.0</td>
<td>1.2 \times 10^{22}</td>
<td>1.15 \times 10^6</td>
<td>36</td>
<td>A typical student on the surface of Pluto</td>
</tr>
<tr>
<td>60.0</td>
<td>1.901 \times 10^{27}</td>
<td>6.98 \times 10^7</td>
<td>1562</td>
<td>A typical student on the “surface” of Jupiter</td>
</tr>
</tbody>
</table>

*The distance of separation means the distance between the centers of the two masses (NOT the distance between the two objects’ edges.)*

13. Use the gravitational acceleration equation to fill in the following table \((G = 6.673 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2)\).

<table>
<thead>
<tr>
<th>Mass of Object Creating the Field (kg)</th>
<th>Distance of Separation* (m)</th>
<th>(g) (m/s²)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.98 \times 10^{24}</td>
<td>6.37 \times 10^6</td>
<td>9.8</td>
<td>On Earth’s surface</td>
</tr>
<tr>
<td>5.98 \times 10^{24}</td>
<td>6.47 \times 10^6</td>
<td>9.5</td>
<td>60 miles above Earth’s surface</td>
</tr>
<tr>
<td>5.98 \times 10^{24}</td>
<td>42.3 \times 10^6</td>
<td>223</td>
<td>Above Earth’s surface in a geosynchronous orbit</td>
</tr>
<tr>
<td>1.2 \times 10^{22}</td>
<td>1.15 \times 10^6</td>
<td>60.55</td>
<td>On Pluto’s surface</td>
</tr>
<tr>
<td>1.901 \times 10^{27}</td>
<td>6.98 \times 10^7</td>
<td>26.04</td>
<td>On Jupiter’s “surface”</td>
</tr>
</tbody>
</table>

*The distance of separation means the distance between the centers of the two masses (NOT the distance between the two objects’ edges.)*

Identify the following statements as being **True** or **False**.

14. Astronauts on the space station do not weigh anything.  **F**
15. There is no gravity on the space station.  **F**
16. There is no gravity anywhere in space.  **F**
17. There is no gravity in a vacuum  **F**
18. Orbiting astronauts are not accelerating.  **F**
19. If the Earth were not spinning, then there would be insufficient gravity to hold us on its surface.  **F**
20. The gravitational acceleration of a free-falling object depends upon its mass.  **F**
21. Isaac Newton compared the acceleration of a falling apple to the acceleration of the **falling** moon. In his comparison, he proved that the moon accelerates at a rate that is 1/3600-th of the apple's rate; he also showed that the separation distance (center to center) between the moon and the Earth was 60 times the separation distance between the apple and the Earth. This is evidence that the acceleration caused by gravity is **inversely** dependent upon the (directly, square, square root, cube, cubed root, etc.) of the separation distance.

Use Newton's gravitational law in a conceptual manner in order to fill in the following blanks.

22. Two objects gravitationally attract with a force of 18.0 N. If the distance between the two objects' centers is doubled, then the new force of attraction is **4.5** N.

23. Two objects gravitationally attract with a force of 18.0 N. If the distance between the two objects' centers is tripled, then the new force of attraction is **2** N.

24. Two objects gravitationally attract with a force of 18.0 N. If the distance between the two objects' centers is halved, then the new force of attraction is **72** N.

25. Two objects gravitationally attract with a force of 18.0 N. If the distance between the two objects' centers is decreased by a factor of three, then the new force of attraction is **162** N.

26. Two objects gravitationally attract with a force of 18.0 N. If the distance between their centers is decreased by a factor of four, then the new force of attraction is **288** N.

27. Two objects gravitationally attract with a force of 18.0 N. If the **mass** of one of the objects is doubled and the **distance** between their centers is doubled, then the new force of attraction is **9** N.

28. Two objects gravitationally attract with a force of 18.0 N. If the **masses** of both of the objects are doubled and the **distance** between their centers is doubled, then the new force of attraction is **18** N.

29. Two objects gravitationally attract with a force of 18.0 N. If the **masses** of both of the objects are tripled and the **distance** between the two objects' centers is doubled, then the new force of attraction is **40.5** N.