Flipping Physics Lecture Notes:
AP Physics 1 - Unit 2b Review
Universal Gravitation, Spring Force, and Circular Motion – Exam Prep
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This lecture is a free part of my AP Physics 1 Ultimate Review Packet. If you find this video useful, I suggest you invest in the rest of the packet.

Universal Gravitation and Gravitational Field:

- The equation for the magnitude of the gravitational force using Newton's Law of Universal Gravitation is: $\left|\vec{F}_g\right| = \frac{Gm_1m_2}{r^2}$
    - G is the Gravitational Constant. $G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$
        - Do not memorize this. It's on the Table of Information provided during the exam!
    - m represents the gravitational masses of the two objects which are interacting via the gravitational force.
    - r is not the radius. r is the distance between the centers of mass of the two objects.
        - This could be confusing, because sometimes r is the radius.
    - The gravitational force is always directed along a line connecting the centers of mass of the two objects.
        - The gravitational force on each of the two masses is always directed toward the other mass.
    - The gravitational forces acting on both masses have the same magnitude and form a Newton's Third Law force pair.
- In the narrow band of altitudes which humans live on this planet, the local gravitational field, g, is nearly constant and can be treated as constant with negligible error and the local gravitational field is directed downward.
    - The gravitational field can be determined by dividing the gravitational force exerted by the field on a test mass by the mass of the test mass.
    - This is easy to remember because it is a rearrangement of the gravitational force equation, like this: $F_g = mg \Rightarrow g = \frac{F_g}{m}$
    - The equation for the gravitational force in that gravitational field is $F_g = mg$, however, a subscript of "object" is missing on the mass.
    - This gravitational force equation describes the interaction between two masses, the mass of the object and the mass of the planet creating the gravitational field.
- The derivation of the gravitational field, g, on the surface of a planet is derived like this:
    - $F_g = m_{\text{object}}g = \frac{Gm_{\text{object}}m_{\text{planet}}}{r^2} \Rightarrow g = \frac{Gm_{\text{planet}}}{\left(R_{\text{planet}}\right)^2}$
- If the only force acting on the object is the gravitational force, then the object is in free fall, and the acceleration of the object has the same magnitude as the gravitational field, g.
    - The units of the free fall acceleration are m/s^2 and the units of the gravitational field are N/kg.
    - These units are the equivalent: $\frac{N}{kg} = \frac{(kg \cdot m)/s^2}{kg} = \frac{m}{s^2}$
- On the AP Physics 1 exam, we can approximate g near the surface of planet Earth to be: $10\frac{m}{s^2}$ or $10\frac{N}{kg}$

The Spring Force:

- An ideal spring force is proportional to its displacement from equilibrium position.
- The equation for the spring force is called Hooke's law and it is: $\vec{F}_s = -k\Delta\vec{x}$
- k is the spring constant and is a measure of how much force it takes to compress or expand a spring per meter. In other words, a larger spring constant will have more resistance to changes in distance from equilibrium position.
    - Typical units for k are newtons per meter.
    - The spring constant is always positive.
- Δx is the displacement of the system/object from equilibrium or rest position.
- The direction of the spring force is always toward equilibrium or rest position.
    - The negative in Hooke's law represents that the spring force and the displacement of the object from rest position are opposite in direction.
- An ideal spring has negligible mass.
- The magnitude of the slope of a graph of spring force vs. displacement from equilibrium position is the spring constant.

Circular Motion:

- The linear velocity of an object moving along a circular path is called tangential velocity which is always directed perpendicularly to the radius describing the path and parallel to the path itself.
- An object moving along a circular path, must have a centripetal acceleration which is always directed inward toward the center of the circle.
    - Acceleration equals change in velocity over change in time. And velocity is a vector, which means it has both magnitude and direction.
    - The reason an object moving along a circular path must have a centripetal acceleration is because the direction of the tangential velocity of the object is always changing.
    - Centripetal acceleration equals the square of tangential speed divided by radius.
        - $a_c = \frac{{v_t}^2}{r}$
- An object, moving along a circular path at a constant speed, can be defined using the following terms:
    - The time it takes the object to complete one circle is defined as the period the symbol for which is T.
    - The number of revolutions completed by the object per second is defined as frequency. The symbol for which is f.
        - The units for frequency are cycles per second or hertz, Hz.
        - These two terms are inversely related to one another to using the following equation: $T = \frac{1}{f}$
- Starting with the equation for speed, we can derive the equation for the period of an object traveling at a constant speed in a circular path in terms of radius, r, and tangential speed, v. And yes, you recognize that, for speed here mr.p is using "v" and you can let that go, correct?
    - $\text{speed} = \frac{\text{distance}}{\text{time}} \Rightarrow v_t = \frac{\text{Circumference}}{T} = \frac{2\pi r}{T} \Rightarrow T = \frac{2\pi r}{v_t}$
- Centripetal force is the net force in the in direction or the "center seeking" force which causes the centripetal acceleration of the object in toward the center of the circle.
    - The equation for centripetal force is: $\sum \vec{F}_{in} = m\vec{a}_c$
        - The centripetal force is not a new force
        - The centripetal force is never in a free body diagram.
        - When summing the forces in the in-direction, the direction "in" is positive and the direction "out" is negative.