Physics 107 Test 1 (Hokin)
September 28, 2011

Name __________________________

Each problem is worth 10 points.

Constants

\[ G = 6.67 \times 10^{-11} \text{Nm}^2/\text{kg}^2 \] universal gravitation constant
\[ c = 3.0 \times 10^8 \text{m/s} \] speed of light

\[ g = 9.8 \text{m/s}^2 \] gravitational acceleration at surface of Earth
\[ R_e = 6.4 \times 10^6 \text{m} \] Earth radius

Equations

\[ d = vt \] (if velocity constant)
\[ v = at \] (if acceleration constant)
\[ d = \frac{1}{2} at^2 \] (if acceleration constant)

\[ a_c = \frac{v^2}{r} = r \omega^2 \] centripetal acceleration, \( \omega \) is angular speed in rad/s

\[ F = ma \] Newton's law relating force, mass and acceleration

\[ F_c = \frac{mv^2}{r} = m \omega^2 \] centripetal force (from \( F = ma \) for circular motion)

\[ F_g = G \frac{mM}{r^2} \] gravitational force between masses \( m \) and \( M \)

\[ \mathbf{p} = m \mathbf{v} \] momentum
1. In physics we often have two different theories that are consistent with current observations. How do physicists determine which theory is "better"?

Do exact observation that distinguishes between theories.

2. Draw a sketch of the night sky displaying a few fixed stars and showing the retrograde motion of Mars over several days, as viewed from Earth.

3. State an unusual property of water and explain how this property impacts life on Earth.

- Water expands when freezes ⇒ ice floats, fish survive.
- Water heaviest at 34°F ⇒ Fall turnover ⇒ water is oxygenated every fall ⇒ fish breathe.

4. Draw a diagram of the Rutherford gold foil (Geiger-Marsden) experiment. What property of nature did this experiment show?
5. Before air travel, people rode a ship from Southampton, England to New York City, a distance of 3500 miles. The trip typically took five days. Calculate the average speed of the ship in miles per hour.

\[ \text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{3500 \text{ mi}}{5 \times 24 \text{ hr}} = 29 \text{ mi/hr} \]

6. In class, I demonstrated the spark tape with a falling weight, where a spark generator places dots on the paper tape at precise time intervals as the weight falls. A piece of the resulting tape looks like this:

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1 2 3 4 5 6
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Explain how you would analyze this section of tape to determine \( g \). (Note that this piece is from the middle of the fall - the weight is already falling at the first dot shown.) Feel free to label the drawing. (This problem is about methodology – you're not given the time between sparks or a ruler, so you can't actually measure \( g \) numerically.)

Various ways to do it. One way is to measure gap between three dots to get speed at middle dot. Then use time between middle dots to get \( g \):

\[ v_2 = \frac{x_3 - x_1}{t_3 - t_1}, \quad v_5 = \frac{x_6 - x_4}{t_6 - t_4} \]

\[ g = \frac{v_5 - v_2}{t_5 - t_2} \]

\( g \) = But lots of acceptable answers.

7. What is the force of air resistance on a 170-lb skydiver falling at a constant speed of 110 mi/hr?

Zero net force \( \Rightarrow \) \( F_{\text{air}} = 170 \text{ lb} \).
8. Suppose you are standing on frictionless ice skates at rest, and you throw a 180-gram Frisbee forward at speed 9 m/s. Your mass is 150 kg. Calculate the speed at which you are gliding backward after the throw.

\[ p_{\text{Frisbee}} = p_{\text{you}} \]
\[ p = mu \]
\[ (180 \text{ g})(9 \text{ m/s}) = (150,000 \text{ g}) v \]
\[ \Rightarrow v = 9 \text{ m/s} \frac{180 \text{ g}}{150,000 \text{ g}} = 0.01 \text{ m/s} \]

9. Suppose the MINOS experiment measures the speed of neutrinos to be \((1.0004 \pm 0.0006)c\), where \(c\) is the speed of light; in other words, according to MINOS, neutrinos travel at the speed of light “within error bars”. Suppose, also, that the T2K experiment in Japan gets a result similar to MINOS. What conclusion would you draw from these findings regarding the recently-reported CNGS/OPERA result on the speed of neutrinos?

I'd conclude that it's likely that CNGS/OPERA made a mistake and neutrinos actually travel at \(c\).

10. Cavendish measured the universal gravitational constant \(G\) in 1798. Since \(g\) at the Earth's surface was known, and the radius of the Earth, \(R_e\), was known, he was able to calculate the mass of the Earth from Newton's law of gravity. Repeat his calculation to find the mass of Earth, \(M\). (The values of the required constants are all given on the first page of this test.)

\[ F = G \frac{mM}{R^2} = mg \]
\[ \Rightarrow g = \frac{GM}{R^2} \]
\[ \Rightarrow M = \frac{gR^2}{G} = \frac{9.8 \text{ m/s}^2 \left(6.4 \times 10^6 \text{ m}\right)^2}{6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2} \]
\[ M = 6.0 \times 10^{24} \text{ kg} \]