Physics 2A Spring 2020
Discussion 1

TA: Jiashu Han

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1. **Vectors**

   Two cars are initially at the same location. Car A travels 100m in the direction 30 degrees north of east, and car B travels 200m in the east direction. How far apart are the two cars now? Which direction is car B as seen from car A?

   Solution: We can choose the initial position to be the origin $(0, 0)$, and define north to be the y direction and east to be x. Then the position of car A is $\mathbf{a} = (100 \cdot \cos 30°, 100 \cdot \sin 30°)$ m $= (50\sqrt{3}, 50)$ m and the position of car B is $\mathbf{b} = (200, 0)$ m.
   The displacement from A to B is $\mathbf{b} - \mathbf{a} = (200 - 50\sqrt{3}, -50)$ m. The distance is the magnitude of the displacement: $d = |\mathbf{b} - \mathbf{a}| = \sqrt{(200 - 50\sqrt{3})^2 + (-50)^2}$ m.
   Define the angle between south ($-y$ direction) and the displacement as θ, then $\tan\theta = \frac{200-50\sqrt{3}}{50} = 4 - \sqrt{3}$, so $\theta = \arctan(4 - \sqrt{3})$.

2. **Physical quantities and units**

   Make a guess on how energy is related to mass and velocity (Hint: energy has unit kg·m^2/s^2).

   Solution: Mass (m) has units of kg, and velocity (v) has units of m/s, so the expression mv^2 gives us the same unit as energy. The (non-relativistic) kinetic energy is $\frac{1}{2}mv^2$, so besides a factor of 1/2, it does match our result. This technique is useful for checking your solution of a problem.

3. **Kinematics**

   A ball is dropped from 100 m above the ground. At what height is the ball after 3 seconds? What is its velocity? (Assume the acceleration is $g = 10$ m/s^2) Also what is the general expression of the ball's height as a function of time in terms of the quantities given?

   Solution: The kinematic equation we want to use here is $x = x_0 + \frac{1}{2}at^2$, where x is the position of the ball as a function of time, x_0 is the initial position (100 m), a is the acceleration of the ball, and t is the time elapsed since the ball is released. Note that $a = -g$ because the acceleration is downward. Plugging in all the numbers, we get $x = 55$ m. For the velocity, we differentiate the first equation with respect to time: $v = dx/dt = at = -30$ m/s. The general expression of the ball's height is just the first equation we wrote down.

4. **Estimation**

Roughly estimate how many soda cans can fit in the Geisel Library.

Solution: We are making very rough estimate here so any reasonable guess is fine. The typical volume of a soda can is about half a liter ($\approx 10^{-3}$ m^3), so $V_{\text{can}} \sim 5 \cdot 10^{-4}$ m^3. Geisel has 8 floors, and the typical height of a floor is 4 meters, so the building has a total height of about 30 m. Since it is not much taller than it is wide, we approximate it as a cube, so its volume is $V_{\text{library}} \sim 27000$ m^3. Taking the ratio between the two volumes, we get about $5 \cdot 10^7$ or 50 million.