Homework 1 Solution

SABIC: Physics

Due January 21, 2016

Reading (Due April 1, 2015):

Read Chapter 1.

Problem 1: practice with estimation

(a) **How many kernels of corn does it take to fill a 2 liter soda bottle?** 2 liters is 2000cm^3, and a kernel of corn is about $(0.5\text{cm})^3 = .1\text{cm}^3$. So that puts us with $2000/.1 \simeq 10000$ kernels.

(b) **How many liters of gasoline are used in the United States in one day?** There are let's say 100 million $= 10^8$ cars in the USA. Each car need to fill their gas tank once every other week ($\simeq 20$ days), and a gas tank holds $\simeq 20$L of gasoline. That means that each driver uses $\simeq 1$L of gas a day, and with 100 million cars, we'd expect about 100 million liters of gasoline a day.

Problem 2: conceptual

(a) **What physical phenomena could you use to define a time standard?** There are a bunch of good answers. You can use the sunrise to define a day, which is a good answer. The current answer has to do with a vibrational mode of a cesium atom, whose frequency is measured very precisely. That's how atomic clocks work.

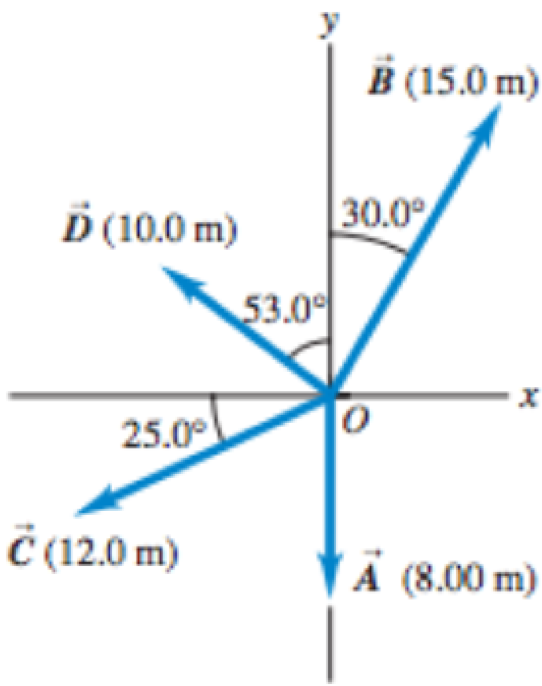
(b) **Describe how you could measure the thickness of a sheet of paper with an ordinary ruler.** Take a bunch of identical papers and stack them, then divide the answer by the number of papers in the stack.

(c) **Can you find two vectors with different lengths that have a vector sum of zero? What length restrictions are required for three vectors to have a vector sum of zero? Explain your reasoning.** To the first part, no, you can't: you need two vectors of the same magnitude to sum to zero, and in addition they have to point in exactly opposite directions. We call one of the vectors $\vec{v}$, then the other vector we call $-\vec{v}$.

(d) **(i) Does it make sense to say that a vector is negative?** No. Vectors have a magnitude (which is always positive), and a direction, which is an angle and therefore also always positive. **(ii) Does**

it make sense to say that one vector is the negative of another? Does your answer here contradict what you said in part (i)? Sure–that means a vector with the same magnitude pointing in the opposite direction. That's not contradictory, since we're not saying either $\vec{v}$ or $-\vec{v}$ is negative, just that they're negatives *of* each other.

Problem 3: vector addition



(a) **For the vectors $\vec{A}$ and $\vec{B}$in the figure, find the magnitude and direction of (i) $\vec{A}+\vec{B}$, (ii) $\vec{A}-\vec{B}$, (iii) $-\vec{A}-\vec{B}$, and (iv) $\vec{B}-\vec{A}$.** To add vectors, you have to add components. I'll do out part (i) and then give the answers to the rest. $\vec{A} = -8\text{m}\ \hat{\jmath}$, and $\vec{B} = (15 \sin 30°\hat{\imath} + 15 \cos 30°\hat{\jmath}\text{m} = 15/2\hat{\imath} + 15\sqrt{3}/2\hat{\jmath}$. So $\vec{A}+\vec{B} = 15\sqrt{3}/2\hat{\imath} - 0.5\hat{\jmath}\text{m}$. The magnitude is $|\vec{A}+\vec{B}| = \sqrt{(15/2)^2 + (15\sqrt{3}/2 - 8)^2} = 9$, while the angle is $\tan^{-1} V_y/V_x = 34°$ above the x-axis. For the others:

$$|\vec{A}-\vec{B}| = 22\text{m} : \simeq 70° \text{ below the } -x \text{ axis.} \tag{1}$$

$$|-\vec{A}-\vec{B}| = |\vec{A}+\vec{B}| = 9 : \simeq 34° \text{ below the } -x \text{ axis} \tag{2}$$

$$|\vec{B}-\vec{A}| = |\vec{A}-\vec{B}| = 22 : \simeq 70° \text{ above the } x \text{ axis} \tag{3}$$

(b) **A spelunker is surveying a cave. She follows a passage 180 m straight west, then 210 m in a direction $45°$ east of south, and then 280 m at $30°$ east of north. After a fourth unmeasured displacement, she finds herself back where she started. Use a scale drawing to determine the magnitude and direction of the fourth displacement.** Call the given vectos $\vec{A}$, $\vec{B}$, and $\vec{C}$, while the 4th displacement we want to find $\vec{D}$. Since she returns to where she started, we must have

$$\vec{A} + \vec{B} + \vec{C} + \vec{D} = 0$$

If you do the math (or draw really carefully), you find that the magnitude is 144m, and the direction is 41° South of West.

Problem 4: vector multiplication

(a) **For the vectors $\vec{A}$, $\vec{B}$, and $\vec{C}$ in the figure, find $\vec{A} \cdot \vec{B}$, $\vec{A} \cdot \vec{C}$, and $\vec{B} \cdot \vec{C}$.** $\vec{A} \cdot \vec{B} = |A||B| \cos(60° - (-90°)) = (8m)(15m) \cos 150° = -104\text{m}^2$. Similarly, we have $\vec{A} \cdot \vec{C} = 40.6\text{m}^2$, and $\vec{B} \cdot \vec{C} = -148\text{m}^2$.

(b) **For the vectors $\vec{A}$ and $\vec{D}$ in the figure, find the magnitude and direction of $\vec{A} \times \vec{D}$ and $\vec{D} \times \vec{A}$.** The magnitude of both is the same, and it's $|A||D| \sin 127° = 63.9\text{m}^2$. By the right hand rule, $\vec{A} \times \vec{D}$ is in the $-z$ direction, while $\vec{D} \times \vec{A}$ is in the $+z$ direction.s