EECS 16A Designing Information Devices and Systems I
Spring 2015 Homework 0

This homework is due January 29, 2015, at 5PM.

1. **Python Hello World**

   Download and follow the steps in the Python Installation Guide document to install and run iPython. Complete the "Introduction to Python" in the file `Homework0.ipynb`.

2. **Jobs and Ecosystem**

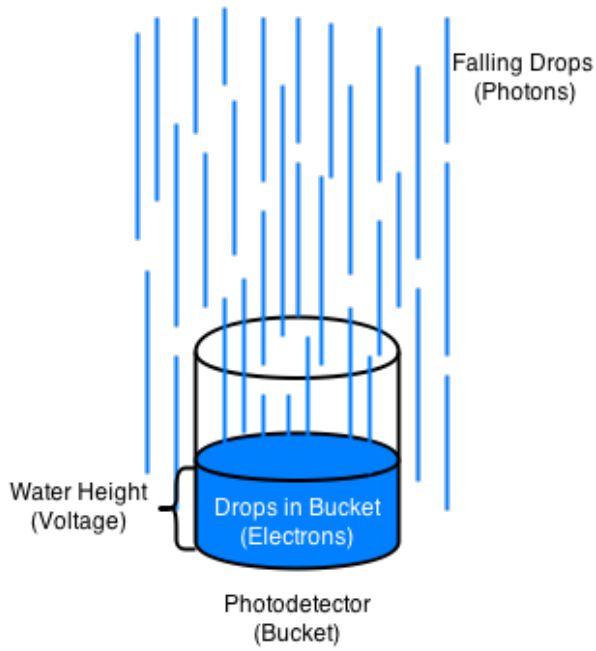
   Consider this chart from the article *Which Jobs Pay the Best at Apple?*[1]. Assuming you were trying to design a choice of courses to match the needs of future jobs at Apple, go through the EECS course list[2] and match courses to the following job titles: Software Engineer, Hardware Engineer, Product Design Engineer.

[1] https://www.businessvibes.com/blog/which-jobs-pay-best-apple
[2] http://www-inst.eecs.berkeley.edu/classes-eecs.html

3. Basic Electrical Quantities

As you learned in lecture, a photodetector converts light (photons) into charge (electrons).

To get an idea of how we might choose the photodetector's size, imagine a photodetector is like a bucket you leave out in the rain.

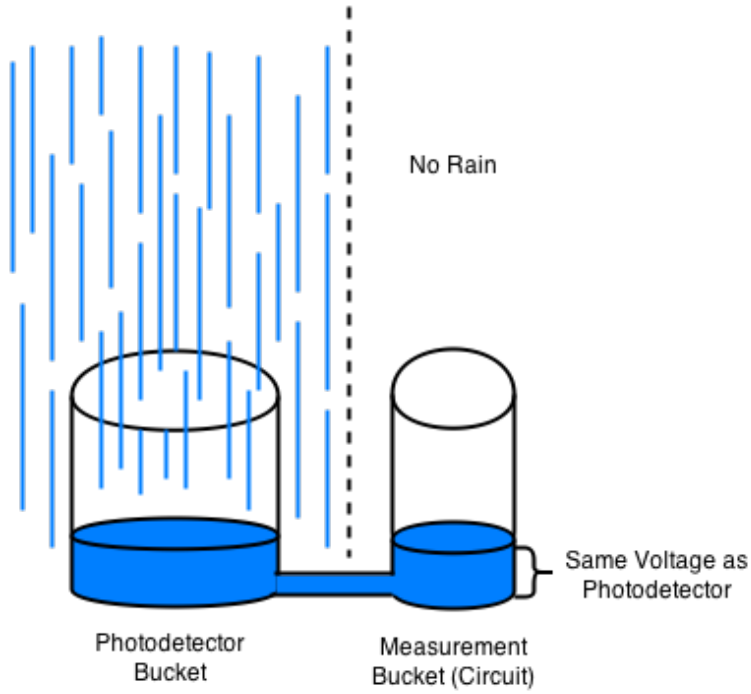


Raindrops (representing photons) are collected as water (representing electrons). The height of the water represents the voltage you would measure in the photodetector.

(a) Assume that the rain falls evenly over the entire area. if you were to double the area of the bucket, how would it change the height of the water?

(b) Now imagine that we can't measure the water level in the photodetector directly – instead we have to connect it to a separate measurement bucket, representing a circuit.

No rain falls on the measurement bucket, and all its water comes from the photodetector bucket:



Water will flow through the connecting pipe until the heights are equal in both buckets, so reading the water level in the measurement bucket gives you the level in the detector.

Assume that in a certain period of time a constant level of rain accumulates per unit area. Let's call this constant R. It has units of

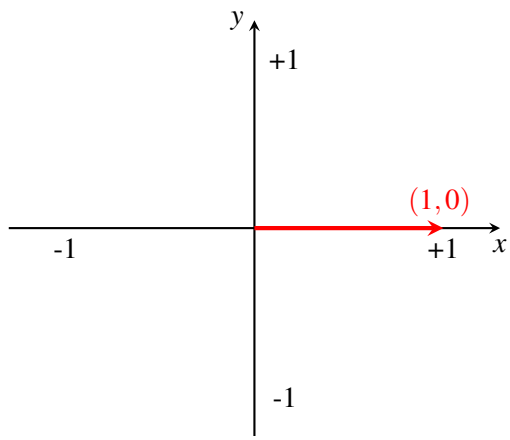
$$\frac{\text{cm}^3 \text{ of rain fallen}}{\text{cm}^2 \text{ of area}} = \text{cm}$$

Let A_p be the area of the photodetector bucket, and A_c be the area of the circuit (measurement) bucket. Write an expression for h, the height of the water in either bucket, as a function of R, A_p, and A_c.

(c) Given a fixed measurement bucket, what would you choose for the area of the photodetector bucket and why?

4. Introduction to Linear Algebra

Consider the vector $\begin{bmatrix}1\\0\end{bmatrix}$ plotted below:



(a) What is the vector that you get after rotating the given vector 90 degrees counterclockwise? Plot the result in the iPython notebook.

(b) Now, we have not defined matrices yet, but consider the matrix $\begin{bmatrix}0 & -1\\1 & 0\end{bmatrix}$. We will soon define matrix multiplication, but for now, use the following algorithm:

$$\begin{bmatrix}a & b\\c & d\end{bmatrix}\begin{bmatrix}x\\y\end{bmatrix}=\begin{bmatrix}ax+by\\cx+dy\end{bmatrix}$$

Multiplying a 2x2 matrix by a 2x1 vector results in a 2x1 vector. We will understand this more as we go along.

What do you get when you multiply $\begin{bmatrix}0 & -1\\1 & 0\end{bmatrix}\begin{bmatrix}1\\0\end{bmatrix}$? What would be an appropriate name for the matrix $\begin{bmatrix}0 & -1\\1 & 0\end{bmatrix}$?

Now, repeat this matrix multiplication in the iPython notebook and check your result.

(c) Let the vector $\begin{bmatrix}x\\y\end{bmatrix}$ make the angle ϕ with the x-axis. Given that $x^2+y^2=1$, what are x and y in terms of ϕ?

Now, rotate $\begin{bmatrix}x\\y\end{bmatrix}$ by θ. What is the new vector? Calculate the new coordinates using basic trignometric identities.

(d) Consider the operation:

$$\begin{bmatrix}cos(\theta) & -sin(\theta)\\sin(\theta) & cos(\theta)\end{bmatrix}\begin{bmatrix}x\\y\end{bmatrix}$$

where $\begin{bmatrix}x\\y\end{bmatrix}$ makes the angle ϕ with the x-axis. What is the result vector in terms of ϕ and θ?

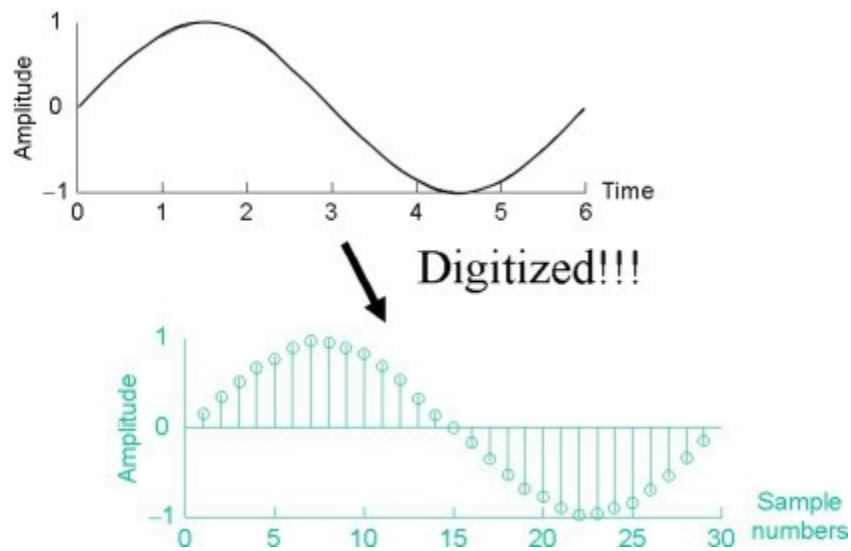
(e) There is an image of a simple house created with multiple line segments in the iPython notebook. Pick a value for θ by which you would like to rotate the figure, and then run the code to observe the results.

5. Sampling and Aliasing

Watch the short video *Affordable Teslas: Norway's Only Bargain?*[3], by the guidebook author and travel TV host Rick Steves[4], in which he describes Norway's love of Tesla electric vehicles. Pay close attention to how the Tesla's wheels appear to turn around 00:50.

The wheels appear to spin slowly *backwards*! Known traditionally as the *carriage wheel effect*, this phenomenon takes its name from the screen rendition of horse-driven wagon wheels in old Western movies.

Another name for this is *aliasing*, at the interface of the analog and digital worlds. Higher frequencies can "fold down" to lower frequencies if a continuous-time signal is *sampled* into a discrete-time signal. Sampling is the process of taking point values from a function over *real numbers* to get a function over *integers*. Here's an example of sampling:



In the figure above, the black sine wave is the continuous time signal $y(t)$, and the blue stem plot is the discrete time signal $y_d(n)$. Notice that for every second, there are five samples – the *sampling frequency* f_s is 5 Hz. Conversely, the period between samples, T_s, is $\frac{1}{5}$ s.

To convert from $y(t)$ to $y_d(n)$, we use this formula:

$$\forall n \in \mathbb{Z},\ y_d(n) \ = \ y(nT_s)$$

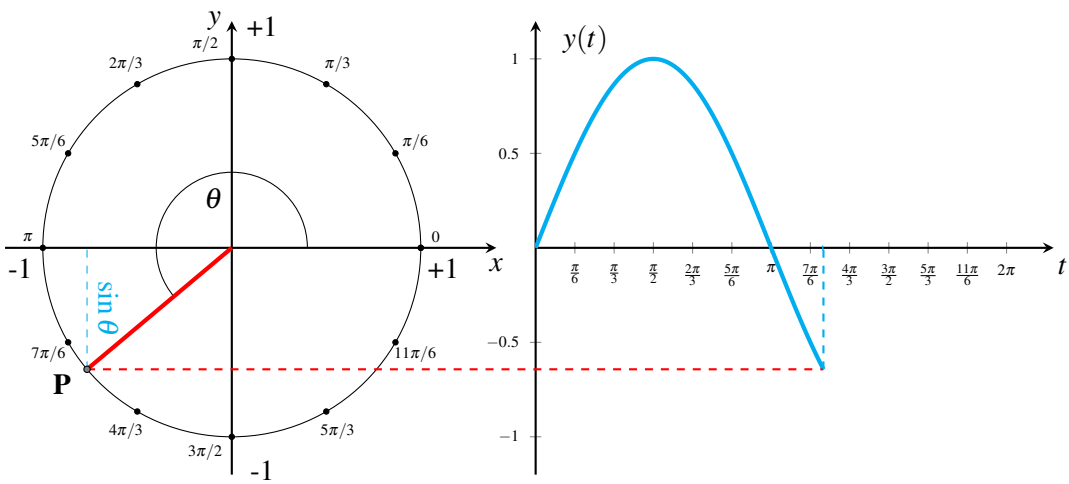
For example, in the figure above, $y_d(10)$, the height at the tenth sample, is given by $y(10 \times \frac{1}{5}) \ = \ y(2)$. Check the plot to make sure you agree with this.

Now let's get back to the Tesla and aliasing. Model the wheel as a circle of unit radius (see the figure below)[5], turning *counterclockwise* at a steady rate. (Even though it's turning clockwise in the video, we'll go with counterclockwise for convention.)

[3] http://blog.ricksteves.com/blog/affordable-teslas-norways-only-bargain/

[4] https://www.ricksteves.com/about-rick

[5] Adapted from http://tex.aspcode.net/view/635399273629833626263562/unit-circle-sinx-radians-on-x-axe.



The angle that point **P** makes with the x axis at time t is $\theta(t)$. Then, $y(t) = sin[\theta(t)]$ is the height of P at time t – this is the second graph in the figure above.

Assume that **P** is initially at angle 0 ($\theta(0) = 0$), and the wheel rotates counterclockwise at a constant angular speed of f_0 revolutions per second. Here f_0 is a positive quantity measured in Hertz.

(a) What is the formula for **P** ($y(t)$) in terms of f_0? *Hint: Show* $\theta(t) = 2\pi f_0 t$. If we sample the function at a sampling rate of f_s, what is the formula for y_d in terms of f_0 and f_s?

Suppose we shine a strobe light onto the wheel. The strobe light flashes every T_s seconds, capturing a sample of the wheel's position. We only record samples every T_s seconds, so our *sampling frequency* is

$$f_s = \frac{1 \text{ sample}}{T_s \text{ seconds}}$$

For each flash of the strobe light, we record the value of $y(t)$. The signal y_d is the discrete-time counterpart of the continuous-time signal y. You'll discover that if the sampling frequency f_s is "too low", the rotation of the wheel appears distorted.

(b) Suppose the strobe flashes at a rate $f_s = f_0$. Determine a reasonably simple expression for the sequence of values $y_d(n)$. Plot $y(t)$ and mark the time points when you would sample the function to get values for y_d. Describe the perceived motion of the wheel.

(c) Suppose the strobe flashes every $T_s = T_0/4$ seconds. Determine a reasonably simple expression for the sequence of values $y_d(n)$. Plot $y(t)$ and mark the time points when you would sample the function to get values for y_d. Describe the perceived motion of the wheel.

(d) Suppose the strobe flashes at a rate $f_s = 1.5 f_0$. Determine a reasonably simple expression for the sequence of values $y_d(n)$. Plot $y(t)$ and mark the time points when you would sample the function to get values for y_d. Describe the perceived motion of the wheel.

(e) Which of the scenarios above most closely resembles the perceived motion of the wheels in the video? When does this sampling occur in the process of recording the video?