Description of Assignment

Please complete this chapter quiz without help from another student. Do not share answers either. If someone contacts you and says they need help on a certain problem, please just tell them that you cannot help them or discuss this quiz at all. Do not share code. Do not share information. Do not share hints. Do not talk to them about this quiz. You cannot contact me to get help on the problems. If you are unsure of whether or not you can use something just fall back to the following statement: "***You may not contact another human being for help on this quiz. If the answer is on the internet then it is fair game".***

Therefore, you are on your own to find the answers or just infer some assumptions from any lack of information. The answers are there, you just need to go find them. Zoom lectures, youtube videos, and documentation like Wikipedia, etc are all valid sources of information.

This quiz will be distributed to you and due within one week. Due to the fact that this assignment is an assessment of your performance and timeliness is part of that assessment, no late assessments will be accepted. My recommendation is for you to turn in the assignment at least an hour early so you don't run into any technical problems.

Submission Checklist - SEND EVERYTHING VIA EMAIL

1.) Name on document
2.) Digitally signed document
3.) Converted to a SINGLE PDF
4.) All python scripts imbedded in document either as screenshots (not cell phone photos) or text
5.) Results from computer software is included as a figure with properly labeled axes
6.) References section included

Honor Pledge

I, *INSERT NAME HERE*, have read the description above and acknowledge that I did not contact another human being whether digitally or face to face to receive or give help on this quiz. I acknowledge that the answers below are in my own words and reflect my understanding of the material.

INSERT DIGITAL SIGNATURE

DATE

1.) My graduate student 3D printed a wheel with 12 spokes on it each equidistant from each other. He created code to measure the angular velocity based on the time between successive measurements using a light sensor as each spoke passes over the sensor. First draw a picture of this tachometer and then explain how you would compute the angular velocity of the wheel.

1-1 Setup

Assuming the time it takes light to travel from the spoke to the wheel to be negligible, this problem can be set up as follows:

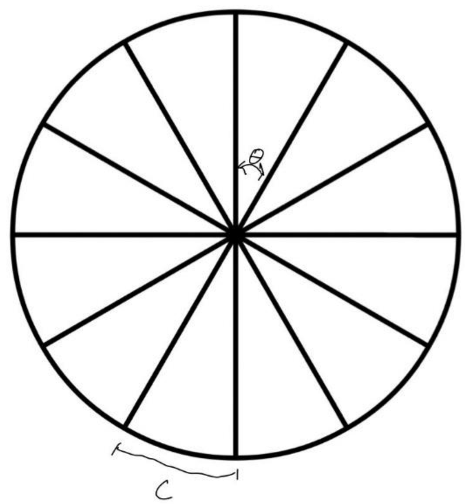

Figure 1.1 (Representation of wheel with 12 spokes equidistant apart.)

1-2 Description

As the wheel rotates, the spoke casts a shadow over the light sensor. The light sensor, assuming a photocell, changes resistance as light level changes.

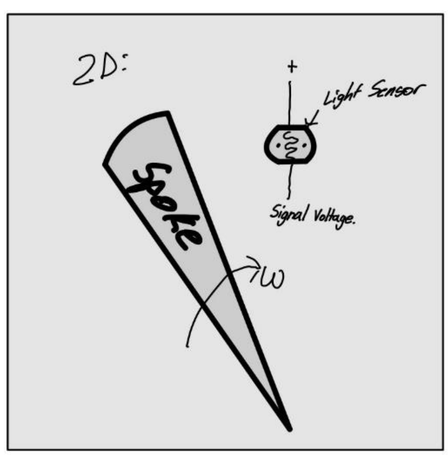

Figure 1.2 (Zoomed in portion of wheel, to represent spoke passing light sensor.)

One could use the setup in Figure 1.2 to infer the angular velocity of the wheel.

1-3 Solution

To begin this problem, we must create variables. As shown in Figure 1.1, let θ be the angle between each spoke. This angle can be found since there are 12 spokes equidistant from each other. The following equation can be used to express this angle:

$$\theta = \frac{1}{n}(360^{o})$$

where n is the number of spokes on the wheel. Plugging in our values, we can find the following:

$$\theta = \frac{1}{12}(360°)$$
$$\theta = 30° \text{ or } \frac{\pi}{6} radians$$

Using the photocell voltage drops, we could write a time stamp correlated to a voltage drop. If we notice a voltage drop at time "t_1", and then at time "t_2", we could express the change in time between the drops "Δt" as follows:

$$\Delta t = t_2 - t_1$$

This change in time between voltage drops is also the time it takes between spoke passes in front of the light sensor.

Finally, we could express the angular velocity of the wheel, "ω", as follows:

$$\omega = \frac{\theta}{\Delta t}$$
$$\omega = \frac{\pi}{6\Delta t}$$
$$\omega = \left(\frac{\pi}{6}\right)\left(\frac{1}{t_2 - t_1}\right)$$

TABLE 9.3 Platinum RTD: R Versus T (U.S. Calibration)[a]

T (°C)	$R(\Omega)$	T (°C)	$R(\Omega)$	T (°C)	$R(\Omega)$
−100	59.57	100	139.16	300	213.92
−90	63.68	110	143.01	310	217.54
−80	67.78	120	146.85	320	221.14
−70	71.85	130	150.68	330	224.74
−60	75.91	140	154.49	340	228.32
−50	79.96	150	158.29	350	231.89
−40	83.99	160	162.08	360	235.44
−30	88.01	170	165.86	370	238.99
−20	92.02	180	169.63	380	242.52
−10	96.01	190	173.39	390	246.05
0	100.00	200	177.13	400	249.56
10	103.97	210	180.86		
20	107.93	220	184.58		
30	111.87	230	188.29		
40	115.81	240	191.99		
50	119.73	250	195.67		
60	123.64	260	199.35		
70	127.54	270	203.01		
80	131.42	280	206.66		
90	135.30	290	210.30		

[a] $R = 100\ \Omega$ at 0°C.

2.) Look at the figure above for RTD devices. Since this is a Google Doc you can make that Figure bigger if you have a hard time reading it. Plot temperature on the x-axis and the resistance in Ohms on the y-axis. Is it linear? Assume you measure the resistance in the Ohms to be 129 Ohms. According to the table, what would be the temperature in C? Plot that single data point on your graph as well. The resistance data is in plain text on the last page of this document and the temperature is just in intervals of 10C so you can just use numpy.arange().

2-1 Description

In this problem, we will use the given data and plot them using Python. Analyzing this plot, we will tell if the plot is linear or not; furthermore, we will use the given data to find the second part to the problem.

2-2 Solution

To begin this problem, I first transferred the data from Table 9.3 to a ".txt" file. With my temperature data being in my zeroth column and my resistance data being in my first column, I named this file "TestData.txt".

To plot the data, I wrote the following Python script to take the data from the file and plot them:

```python
import numpy as np
import matplotlib.pyplot as plt

data = np.loadtxt('TestData.txt')
T = data[:,0]
R = data[:,1]

plt.plot(T,R)
plt.grid()
plt.xlabel('Temeperature (Celcius)')
plt.ylabel('Resistance (Ohms) ')

plt.show()
```

Figure 2.1 (Code used to plot data from “TestData.txt.)

Running the code above, I received the following plot:

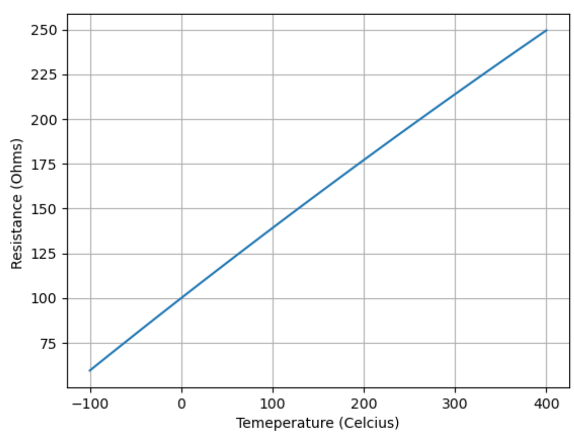

Figure 2.2 (Plot received from running code to plot data.)

Analyzing the plot in Figure 2.2, we can infer the plot is linear.

To find the temperature at 129Ω, we can look at the table. Realizing there is no data point for the resistance at 129Ω, we can interpolate between known values. Here is my data and my interpolation calculations:

<u>Data:</u>

$$R = 129\Omega$$
$$R_1 = 127.54\Omega$$
$$T_1 = 70°C$$
$$R_2 = 131.42\Omega$$
$$T_2 = 80°C$$

<u>Interpolation:</u>

$$T = T_1 + (R - R_1)\frac{(T_2 - T_1)}{(R_2 - R_1)}$$

$$T = 70 + (129 - 127.54)\frac{(80 - 70)}{(131.42 - 127.54)}$$

$$T = 73.76°C$$

To plot this data point, I edited the code I previously wrote to the following:

```python
import numpy as np
import matplotlib.pyplot as plt

data = np.loadtxt('TestData.txt')
T = data[:,0]
R = data[:,1]

plt.plot(T,R)
plt.plot(73.76,129, marker="o", markerfacecolor = "red")
plt.grid()
plt.xlabel('Temeperature (Celcius)')
plt.ylabel('Resistance (Ohms) ')

plt.show()
```

Figure 2.3 (Edited code used to plot data point.)

Running the code above, I received the following plot:

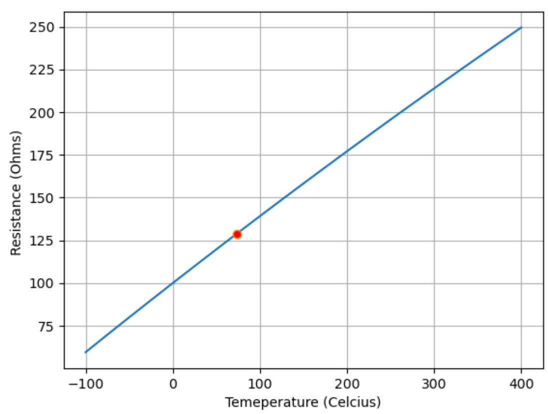

Figure 2.4 (Plot received from edited code.)

3.) The MPXV5010DP pressure transducer measures differential pressure in a pitot probe. The reference voltage (delta pressure = 0) is 2.5V. Assume that you measure a voltage of V = 2.51 which is not a large change in voltage. What would be the computed windspeed from the pitot probe sense. Note that density is 1.225 kg/m^3 at sea-level in SI units.

$$\Delta V = V - 2.5$$
$$\Delta P = 1000\Delta V$$
$$U = \sqrt{(2\Delta P/\rho}$$

3-1 Solution:

Given that the measured voltage is 2.51V, we can calculate voltage change, ΔV, using the following equation:

$$\Delta V = V - 2.5$$
$$\Delta V = 2.51 - 2.5$$
$$\Delta V = 0.01V$$

Knowing $\Delta V = 0.01V$, we can now calculate pressure change, ΔP, using the following equation:

$$\Delta P = 1000\Delta V$$
$$\Delta P = 1000(0.01)$$
$$\Delta P = 10Pa$$

Knowing $\Delta P = 10Pa$ and density, $\rho = 1.225\frac{kg}{m^3}$, we can now calculate windspeed, U, using the following equation:

$$U = \sqrt{\frac{2\Delta P}{\rho}}$$
$$U = \sqrt{\frac{2(10)}{1.225}}$$
$$U = 4.04\frac{m}{s}$$

4.) This question deals with an IMU
   a.) What is an IMU?
   b.) What does IMU stand for?
   c.) What sensors make up an IMU and how do they work?
   d.) The following sensor on Adafruit is an IMU but they call it a 9DOF sensor. Why 9 and what is DOF? https://www.adafruit.com/product/2472
   e.) This sensor here though is a 10DOF sensor. Why 10? What extra sensor does this one have that the 9DOF does not? https://www.adafruit.com/product/1604 (Note this sensor is discontinued)
   f.) What is the communication protocol between this breakout board and your microcontroller.

4.a - What is an IMU?

An IMU is a type of sensor that is used to measure acceleration, angular velocity, and magnetic fields.

4.b - What does IMU stand for?

IMU stands for "Inertial Measurement Unit."

4.c – What sensors make up an IMU, and how do they work?

An IMU is made up of the following three sensors:

1. Accelerometer

An accelerometer is a sensor used to measure acceleration. The internals of an accelerometer can be shown as follows:

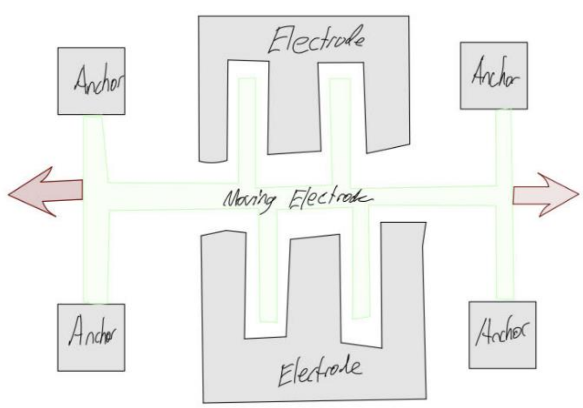

Figure 4.c.1 (Internal representation of accelerometer.)

As the moving electrode experiences acceleration, the moving electrode moves relative to the anchors. This motion causes a capacitance change between electrodes. The capacitance change can be read by a change in voltage.

2. Gyroscope

A gyroscope is a sensor which measures angular velocity. The internals of a gyroscope work by consistently moving a mass back and forth about a particular axis. When an angular velocity occurs, it causes the mass to twist relative to the anchors. This twist causes a capacitance change which can be read by a change in voltage.

3. Magnetometer

A magnetometer is a sensor which measures magnetic fields. A magnetometer typically uses either the Hall Effect or Magneto-resistive Effect.

The Hall Effect uses a capacitive material and allows electrons to flow through that material. When a magnetic field is present, electrons tend to curve to one side of the material, which can be read using a voltmeter.

The Magneto-resistive Effect uses a material that is sensitive to a magnetic field such as FeNi. These materials tend to change their resistive properties when a magnetic field is present. These changes in resistance can be read using a voltmeter.

4.d – Why 9? What is DOF?

DOF most likely stands for "Degrees of Freedom." This sensor is a 9DOF sensor; because, it measures three sets of data about three axes ($3 \times 3 = 9$), nine degrees of freedom. Here are the following degrees of freedom the sensor can measure:

Accelerometer: Acceleration in x direction, y direction, and z direction.
Gyroscope: Angular velocity about x-axis, y-axis, and z-axis.
Magnetometer: Magnetic field strength in x direction, y direction, and z direction.

4.e – Why 10? What extra sensor than the 9DOF?

This sensor is a 10 DOF sensor; because it measures one more degree of freedom than the sensor in 4.d. This sensor also has a barometer, which can measure pressure. Here are the following degrees of freedom the sensor can measure:

Accelerometer: Acceleration in x direction, y direction, and z direction.
Gyroscope: Angular velocity about x-axis, y-axis, and z-axis.
Magnetometer: Magnetic field strength in x direction, y direction, and z direction.
Barometer: Pressure.

4.f – What is the communication protocol?

This breakout board communicates using I^2C 7-bit addresses, particularly "0x19 & 0x1E & 0x6B & 0x77."

5.) Assume you have a solar panel that outputs 200W at 12V.
   a.) First determine the maximum current that would come out of the solar panel.
   b.) Create a voltage divider circuit with a total impedance of 4 kOhms that reduces 12V to 5V. Determine resistors R1 and R2.
   c.) Assume you hook the 5V end of the voltage divider to a voltmeter that has a 4 MOhm input impedance. Assume the solar panel has no output impedance. Compute the current running through the voltmeter and subtract that from your current in part a. Then determine the actual output power of the solar panel assuming this loss from measuring voltage
   d.) Draw a picture of your entire circuit.

5.a – Max current output of solar panel.

Power, "P", is proportional to voltage, "V", and current, "I", as follows:

$$P = VI$$

To apply this formula to our problem, we will solve for current with the given values of power and voltage as shown below.

$$I = \frac{P}{V}$$
$$I = \frac{200}{12}$$
$$I = 16.67 Amps$$

5.b – Voltage divider circuit.

To begin this part of the problem, first let's draw a basic voltage divider circuit.

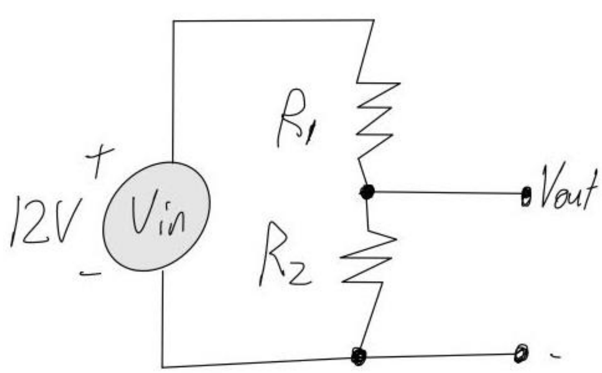

Figure 5.b.1 (12Volt, Voltage Divider Circuit)

In the problem statement, we learn that $R_1 + R_2 = 4000\Omega$, $V_{out} = 5V$, and $V_{in} = 12V$. Using the voltage divider equation, we can solve for R_1 and R_2 as shown below:

$$V_{out} = V_{in}\left(\frac{R_2}{R_1 + R_2}\right)$$
$$R_2 = (R_1 + R_2)\left(\frac{V_{out}}{V_{in}}\right)$$
$$R_2 = 4000\left(\frac{5}{12}\right)$$
$$R_2 = 1666.7\Omega$$
$$R_1 + R_2 = 4000$$
$$R_1 = 4000 - R_2$$
$$R_1 = 4000 - 1666.7$$
$$R_1 = 2333.3\Omega$$

5.c – Voltmeter actual power.

Knowing R_1 and R_2, we can now redraw our voltage divider circuit and add our resistor values and load.

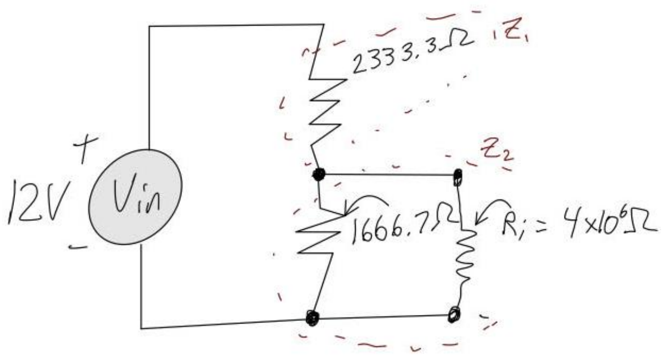

Figure 5.c.1 (Updated Voltage Divider Circuit)

To compute the current running through the voltmeter, we first created equivalent impedance of the resistors shown in Figure 5.c.1.

$$z_1 = 2333.3\Omega$$
$$z_2 = \frac{1666.7(4 \times 10^6)}{1666.7 + (4 \times 10^6)}$$
$$z_2 = 1666\Omega$$

Now, using the voltage divider equation, we will solve for current through the voltmeter.

$$I_1 = 0.003 Amps$$
$$I_R = I_1\left(\frac{z_2}{R_L + z_2}\right)$$
$$I_R = 0.003\left(\frac{1666}{4000000 + 1666}\right)$$
$$I_R = 1.25\mu A$$

For the actual power output, we will subtract this current from the current in 5.a.

$$I = 16.67 - 0.00000125$$
$$I = 16.66$$
$$P = VI$$
$$P = 12(16.66)$$
$$P = 199.92W$$

5.d – My circuit.

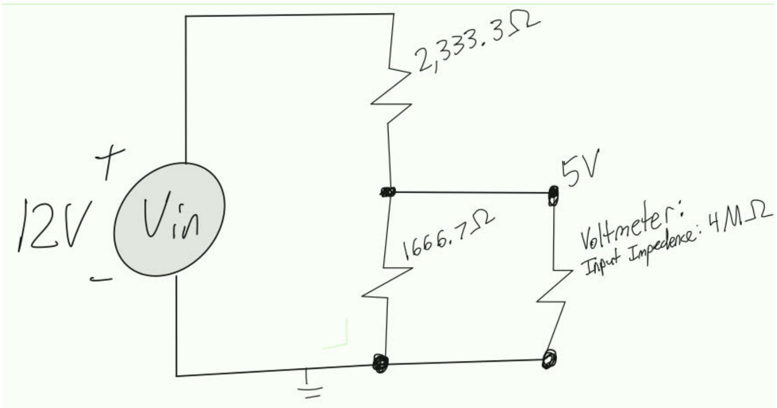

Figure 5.d.1 (Final Voltage Divider Circuit)

6.) Assume you have a rotorcraft that spins rotors at 6000 rpm and you'd like to filter out this frequency from your accelerometer measurements.

a.) To that end, design a low pass Butterworth first order filter with a dc gain of 1 and a dc impedance of 2000 Ohms.

b.) Assume the cutoff frequency is 6000 rpm and compute the capacitance required for this Butterworth filter.

c.) Find a capacitor on Digi key with the same amount of Farads and include a photo and link to that capacitor.

d.) Draw a picture of your filter

6.a – Low pass Butterworth first order filter.

The image below shows a low pass, first order Butterworth filter.

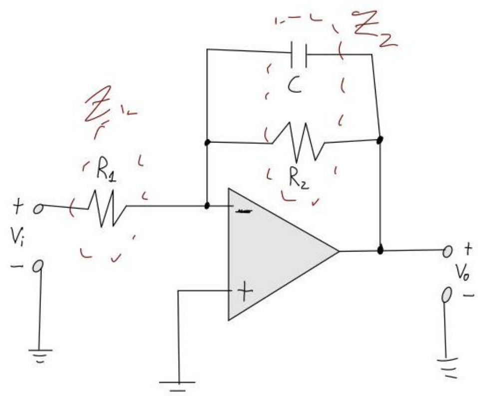

Figure 6.a.1 (First – order, low pass, Butterworth filter)

With a DC gain of 1 and a DC impedance of 2000Ω, we can write the following:

$$Z_C = \infty$$
$$\therefore$$
$$Z_1 = R_1$$
$$Z_2 = R_2$$
$$G = \frac{Z_2}{Z_1}$$
$$G = 1$$
$$\therefore$$
$$R_1 = R_2$$
$$R_1 + R_2 = 2000\Omega$$
$$\therefore$$
$$R_1 = R_2 = 1000\Omega$$

6.b – Capacitance

With a cutoff frequency being 6000rpm, we can convert this to hertz then use the equation for cutoff frequency of this filter to find the capacitance of the capacitor as shown:

$$f_C = 6000rpm$$
$$f_C = \frac{6000}{60}$$
$$f_C = 100Hz$$
$$f_C = \frac{1}{2\pi C R_2}$$
$$\therefore$$
$$C = \frac{1}{2\pi f_C R_2}$$
$$C = \frac{1}{2\pi(100)(1000)}$$
$$C = 1.59\mu F$$

6.c – The Capacitor

Finding the capacitance of the capacitor to be $1.59\mu F \approx 1.5\mu F$, I searched on Digikey.com for a capacitor with these properties. I found the following:

Click here to view capacitor

6.d – My Circuit

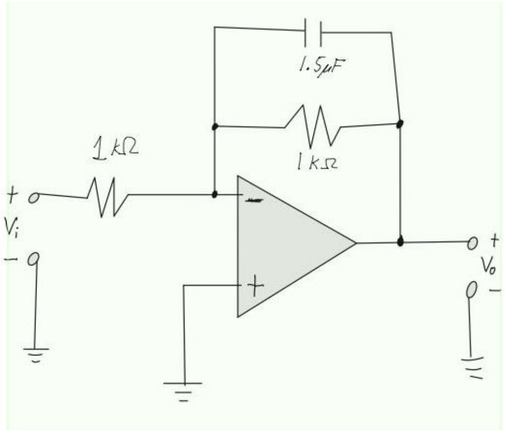

Figure 6.d.1 (My first order, low pass, Butterworth filter)

Resistance Data (Ohms) from -100C to 400C in intervals of 10C

59.57
63.68
67.78
71.85
75.91
79.96
83.99
88.01
92.02
96.01
100.00
103.97
107.93
111.87
115.81
119.73
123.64
127.54
131.42
135.30
139.16
143.01
146.85
150.68
154.49
158.29
162.08
165.86
169.63
173.39
177.13
180.86
184.58
188.29
191.99
195.67
199.35
203.01
206.66
210.30
213.92
217.54

221.14
224.74
228.32
231.89
235.44
238.99
242.52
246.05
249.56