Assignment 03: Data Analytics - Calculations

This assignment includes (3) problems.

Purpose of this assignment

An understanding of the **conservation principles** (mass, energy, momentum, and/or charge) in a system is an important concept for all engineering disciplines. As engineers, we describe systems using **schematic diagrams** and define them with **mathematical models**.

Excel is one of the most commonly used **engineering tools**. In this assignment, you will use Excel to solve complex calculations, perform descriptive statistics, and communicate data using charts. You will perform calculations as you use built-in functions and cell referencing for efficiency of calculations. You will organize and format your spreadsheet to effectively communicate information.

Relevant Course Resources:

Pre-Class Videos	• PCV 2 Introduction to Excel • PCV 3 Creating, Saving, & Sharing Workbooks • PCV 4 Calculations • PCV 5 Functions in Excel • PCV 6 Chart Selection • PCV 7 Formatting Charts • PCV 8 Descriptive Statistics
Course Resources	• Reference1_Excel_Basics_Calculations • Reference2_Excel_ChartSelection
Lecture Slides	• Data Analytics

Organizing Your Work

Pay attention to how you format and organize your work in Excel. For this assignment, the proper formatting is provided on your Excel answer sheet: **ENGR131_ A03_StudentAnswerSheet.xlsx**.

In general,

- Complete all of your work on the Excel answer sheet provided
- Make sure your tables have captions and titles, and your columns have clear labels & units
- Format your cells with reasonable decimal places and data type (In Excel right click, format cells).
- Answer all questions with complete sentences by explicitly referring back to your calculations.

Submission Instructions:

1. Re-name your answer sheet as, **ENGR131_A03_*yourlogin*.xlsx**, where *yourlogin* is your *Purdue Career Account* login.
2. Save your files to your **Purdue Career Account** (This is your Purdue storage space. For more information see https://www.itap.purdue.edu/connections/careeraccount)
3. Submit your work through the designated **Brightspace Assignment Drop box at** https:/purdue.brightspace.com/

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Problem 1 Conservation of Momentum in Space Vehicles

Goal

Given a space launch vehicle of known initial mass and propellant exhaust velocity, calculate the change in velocity of the rocket (delta V) necessary to reach a target orbit. Specifically, your tasks are to:

1. Utilize all known values in the Excel spreadsheet with correct units (Table 1)
2. Populate Table 2. In the first column (Column F), increment the final total vehicle mass starting at 10000 kg and going down to 1000 kg in increments of 100 kg. Use a calculation to increment the values.
3. In Column G of Table 2, calculate ΔV in m/s for each combination of final and initial vehicle mass. Use **absolute and relative cell referencing** to perform the calculations so the values of v_e and m_o could be changed, and the calculations will automatically update.

After these calculations answer these questions:

a) If a delta V of 2000 m/s is needed to get to low-earth orbit, what final vehicle mass will just get the vehicle there? Provide an ***estimate*** based on the results in Table 2.

b) If a delta V of 4500 m/s is needed to get to a geosynchronous orbit, what final vehicle mass will just get the vehicle there? Provide an ***estimate*** based on the results in Table 2.

Background/Technical Content:

Rockets work on the principle of **conservation of momentum**. A **rocket** is an example of conservation of **momentum** because the mass of the system is not constant, since the **rocket** ejects fuel at high velocity to provide thrust. Thus, the weight and mass of the rocket are constantly changing during flight (OpenStax, 2016). Because of the changing mass, we cannot use the standard form of Newton's Second Law of Motion **(F = m*a)** to calculate the acceleration and velocity of the rocket (Ideal Rocket Equation). Instead, the **Tsiolkovsky rocket equation** is used to calculate the change of velocity of the **rocket** as a result of burning a mass of fuel.

Figure 1: Space shuttle Endeavour launches in Nov. 2008. (Dunbar)

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In astrodynamics, the term ΔV, or "delta V", is used to describe how much velocity is needed to get from one place in the solar system to another.

The **Tsiolkovsky rocket equation** calculates how much ΔV is possible based on a specific propellant exhaust velocity and mass fraction as shown below. Note that this is an ideal equation, which neglects aerodynamic lift and drag.

$$\Delta V = v_e ln \frac{m_0}{m_1}$$

Where:

v_e = Propellant exhaust velocity (m/s)

m_0 = Initial total mass of vehicle (kg)

m_1 = Final total mass of vehicle (kg)

$\frac{m_0}{m_1}$ = Mass fraction

Technical Specifications:

A team of engineers is designing a space vehicle to launch to low-earth orbit. The team has a propellant with an exhaust velocity (v_e) of 2000 m/s and a launch vehicle with an initial total mass (m_0) of 10,000 kg. The team plans to use the **Tsiolkovsky rocket equation** to calculate ΔV with this given propellant.

Organizing Your Work:

Inputs:	**Calculations**:		**Outputs:**
Table 1: Constants	Table 2: Column of final total vehicle mass	Table 2: Calculations of ΔV	**1a)** **1b)**
Before you start any calculations, verify all known variables (values and units)	Increment from 10000 kg to 1000 kg in increments of 100 kg.	Calculate ΔV in m/s for each combination of final and initial vehicle mass.	Answer all questions with complete sentences (in 2-3 sentences) AND by explicitly referring back to your calculations

Ideal Rocket Equation. (n.d.). Retrieved January 05, 2021, from https://www.grc.nasa.gov/WWW/K-12/rocket/rktpow.html

Dunbar, B. (n.d.). *The tyranny of the rocket equation*. NASA. Retrieved May 6, 2022, from https://www.nasa.gov/mission_pages/station/expeditions/expedition30/tryanny.html

OpenStax. (2016, August 03). University Physics Volume 1. Retrieved January 05, 2021, from https://courses.lumenlearning.com/suny-osuniversityphysics/chapter/9-7-rocket-propulsion/

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Problem 2 THERMOCOUPLE RESPONSE TIME

Goal

Given performance data for two sensors, your tasks are to:

1. Select the correct chart type to represent the data.
2. Create and properly format one chart that contains both data sets. Add an appropriate and descriptive title, axes labels, and a legend. Include units.
3. Format the data in the chart so each data set is represented by a different style (colors, marker style, etc.) ensuring it is easy to distinguish between the data sets.
4. Set the units on the y-axis (i.e., y-axis bounds) to increments of 1 to enable more precise comparison between the two thermocouples. Set the range of the y-axis to 120 – 131 deg F to maximize the chart area containing the data.
5. Use the chart to understand and compare the performance of the sensors.

Answer the following questions,

2a. What type of chart did you use to represent the data? Justify your choice based on the data.

2b. Which temperature sensor has the faster response time?

2c. Given your answer in 2b and the sizes of the temperature sensors listed in Table 1 below, provide one possible reason for the response time differences. ***Hint: draw a quick sketch of the two temperature sensors that reflects the diameters of each thermocouple and thermowell.***

Background/Technical Content:

A thermowell is a hollow metal tube with one end sealed (see Figure 2). It is usually mounted permanently in a tank or pipe. A sensor or thermocouple is inserted into the thermowell and measures the temperature of the process fluid in the pipe or vessel. Together, the thermowell and the thermocouple make up a temperature sensor.

In her work in a chemical plant, an engineer has noticed that thermowells with a diameter of 0.5 inches have thermocouples of varying sizes in them; for example, some have 0.45 inches diameter thermocouples while others have 0.35 inches diameter or even 0.25 inches diameter thermocouples. The engineer needs to understand if this difference in thermocouple size is resulting in differences in temperature measurements or response time.

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The engineer has collected temperature response data for the two temperature sensors shown in Table 1 below. The sensors were subjected to the same conditions, and the engineer is interested in determining if any differences exist in the temperature measurements between the two sensors. This data is provided to you in the ***Problem 2*** sheet in your Excel student answer sheet.

Temperature sensor	Thermocouple diameter	Thermowell diameter
A	0.45 inches	0.5 inches
B	0.35 inches	0.5 inches

Table 1: Physical description of the two sensors used in the experiment.

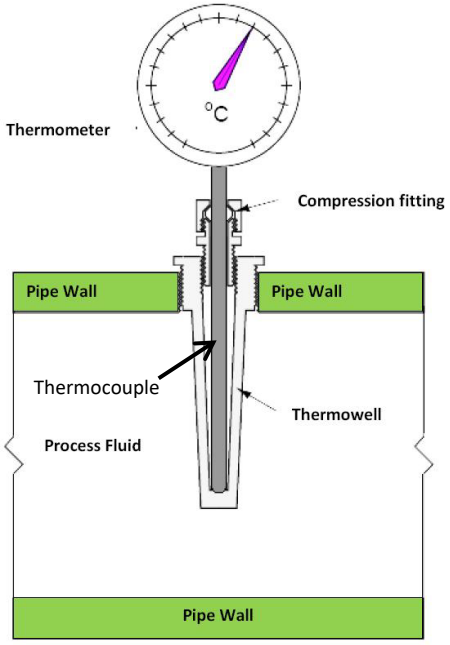

Figure 2: A typical thermowell used in chemical processing. (Thermowells)

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Organizing Your Work:

Inputs:	Calculations:	**Outputs:**
Table 3: Temperature Response Data for Sensor A and Sensor B	Figure 1. Temperature Response for Sensor A and Sensor B	**2a)** **2b)** **2b)**
Before you start any calculations, verify all known variables (values and units)	Create and properly format one chart that contains both data sets.	Answer all questions with complete sentences (in 2-3 sentences) AND by explicitly referring back to your calculations

Thermowells. (n.d.). Retrieved May 6, 2022, from http://www.instrumentationtoolbox.com/2011/01/sensors-used-in-industrial_25.html#axzz3MHfZuBZT

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Problem 3 VOLTAGE MEASUREMENT IN A SPARK PLUG

Goal

Given two experimental datasets, your tasks are to:

1. Use descriptive statistics to analyze the data in Tables 4 and 5. Include minimum, maximum, range, mean, median, mode, variance, and standard deviation.
2. Summarize the descriptive statistics in Table 6.

After these calculations answer the following questions,

3a. Using complete sentences and referencing the actual data, compare the descriptive statistics of the performance of the two designs

3b. If the goal of the spark plug is higher mean breakdown voltage, which spark gap is the better choice for this application? Use complete sentences and refer to the data in your answer.

3c. If the goal of the spark plug is more consistent performance and lower variability, which spark gap is the better choice for this application? Use complete sentences and refer to the data in your answer.

3d. The measured voltage must be above 20 kV in order to ignite the fuel mixture. Using Excel functions (e.g. COUNTIF or SORT), find which spark plug would be the best choice for the ignition application. Use complete sentences and refer to the data in your answer.

Background/Technical Content:

A spark plug works by first applying a voltage across a gap separating the ground electrode and center electrode as shown in Figure 3. The applied voltage leads to a breakdown in the gap, creating a spark. This breakdown voltage is highly dependent on the distance between the center electrode and the ground electrode (spark gap). The heat from the spark sets up the ignition process in the fuel mixture. Your design team is considering two different models of spark plugs. In order to decide which one to manufacture, voltage across the spark gap of two different spark plugs was measured (in units of kV) in 100 different tests. The spark gaps of the two tested spark plugs were 1 mm and 3 mm, respectively. As part of the design team, you are in charge of reporting the results of these tests in order to decide which one performed better with respect to specifications.

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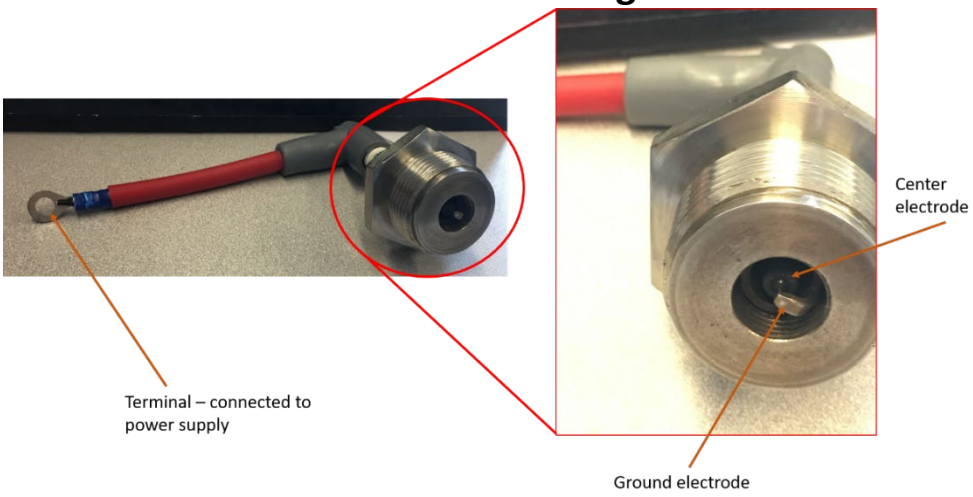

Figure 3: Spark plug

Organizing Your Work:

Inputs:	**Calculations:**	**Outputs:**
Tables 4 and 5: Trial data	Table 6: Summary of descriptive statistics	**3a)** **3b)** **3c)** **3d)**
	Use Excel built-in functions to calculate the: • Minimum • Maximum • Range • Mean • Median • Mode • Variance • Standard deviation	Answer all questions with complete sentences (in 2-3 sentences) AND by explicitly referring back to your calculations and data.

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Check Your Work with the Learning Objectives

Problem 1*:* Conservation of Momentum in Space Vehicles	
Learning Objectives Your work will be graded on demonstration of proficiency of the following learning objectives:	**Did you address this?**
DV04 – Prepare a table for technical presentation with proper formatting with title, row labels, column labels, units and correct decimal places.	
DV01 - Efficient use of engineering tools for basic statistics. Use of automated solutions, such as cell referencing and built in functions.	
SQ01 – Use accurate scientific, mathematical and/or technical concepts, units and/or data in solution.	
EB03 – Clearly articulate reasons for answers with explicit reference to data to justify decisions or to evaluate alternative solutions.	
PC05 - Fully address all parts of assignment by following instructions and completing all work	

Problem 2*: Thermocouple Response Time*	
Learning Objectives Your work will be graded on demonstration of proficiency of the following learning objectives:	**Did you address this?**
DV02 – Select appropriate graphical representation of dataset based on data characteristics such as numerical (discrete or continuous) or categorical (ordinal or nominal)	
DV03 – Justify graphical representation based on data characteristics	
DV05 – Prepare a chart for technical presentation with proper formatting, including title, axes labels, appropriately scaled axes, units and appropriate markers.	
SQ01 – Use accurate scientific, mathematical and/or technical concepts, units and/or data in solution.	
EB03 – Clearly articulate reasons for answers with explicit reference to data to justify decisions or to evaluate alternative solutions.	
PC05 - Fully address all parts of assignment by following instructions and completing all work	

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Problem 3*: Voltage Measurement in a Spark Plug*	
Learning Objectives Your work will be graded on demonstration of proficiency of the following learning objectives:	**Did you address this?**
DV01 - Efficient use of engineering tools for basic statistics. Use of automated solutions, such as cell referencing and built in functions.	
DV04 – Prepare a table for technical presentation with proper formatting with title, row labels, column labels, units and correct decimal places.	
DV06 - Describe the central tendency of data using descriptive statistics (mean, median, mode).	
DV07 – Describe the variability of data using statistical methods (standard deviation, variance).	
DV08 – Make accurate comparisons across groups with explicit reference to data	