Name:

Date:

Start Date of Calc I:

Project 2: The Grand Canyon Skywalk

General Directions:

1. Complete the following questions. Questions are written in **bold**. **Type your answers in BOLD using GREEN-colored font next to each question.**
2. Insert photos/tables directly into the document, as directed.

    a. Using a scanner or a free app (like CamScanner), select the option that converts your photos into “Black and White” or “Black and White with Color” **PDF**. This will provide clarity in reading your solutions. Your insertions **should not look like a photo** when submitted.

    b. When using a free PDF converter app, many free apps include a watermark of the software. Make sure that the **watermark does not cover** any of your solutions. If your solution cannot be read, it will not receive credit.

    c. Your file must be **clear and not fuzzy**. Solutions that are not clear will not receive credit.

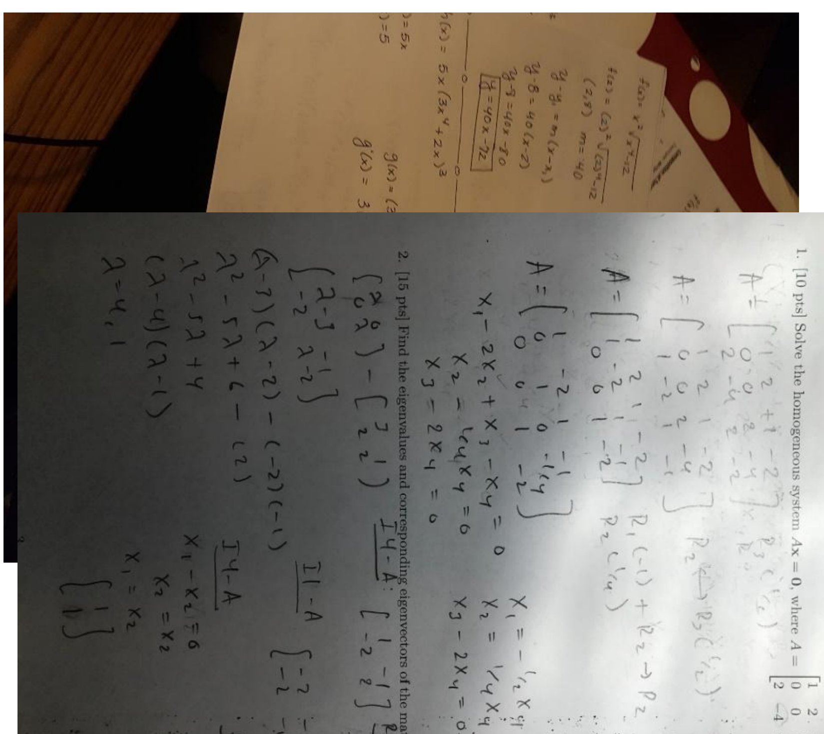
    d. Each of your files should have **your name** on it.

    e. **Crop your insertion** to only include your work. The insertion should not contain other items in view, such as your tabletop or computer.

    f. Insertions should be **orientated facing up** and not upside-down or sideways. The photo should show all of your solutions.

    g. You are expected to clearly communicate your solutions in a **professional and polished manner**. Below is an example of an unacceptable insertion and a properly submitted insertion. Improperly submitted insertions will not receive credit.

        i. Unacceptable Insertions



ii. Proper Insertion

3) $E_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ K & 0 & 1 \end{bmatrix}$ $KR_1 + R_3 \rightarrow R_3 \updownarrow (-K)R_1 + R_3 \rightarrow R_3$

$\boxed{E_1^{-1} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -K & 0 & 1 \end{bmatrix}}$

$E_2 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$ $R_1 \leftrightarrow R_2 \updownarrow R_2 \leftrightarrow R_1$

$\boxed{E_2^{-1} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}}$

$E_3 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & K \end{bmatrix}$ $KR_3 \rightarrow R_3 \updownarrow \frac{1}{K} R_3 \rightarrow R_3$

$\boxed{E_3^{-1} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & \frac{1}{K} \end{bmatrix}}$

4) $A = \begin{bmatrix} 4 & -1 \\ 3 & -1 \end{bmatrix}$ $I_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

① $R_1 + (-1)R_2 \rightarrow R_1$

$\begin{bmatrix} 1 & 0 \\ 3 & -1 \end{bmatrix}$ $E_1 = \begin{bmatrix} 1 & -1 \\ 0 & 1 \end{bmatrix}$ $E_1^{-1} = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$

② $(-3)R_1 + R_2 \rightarrow R_2$

$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ $E_2 = \begin{bmatrix} 1 & 0 \\ -3 & 1 \end{bmatrix}$ $E_2^{-1} = \begin{bmatrix} 1 & 0 \\ 3 & 1 \end{bmatrix}$

③ $(-1)R_2 \rightarrow R_2$

$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ $E_3 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ $E_3^{-1} = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$

$I = E_3 E_2 E_1 A$

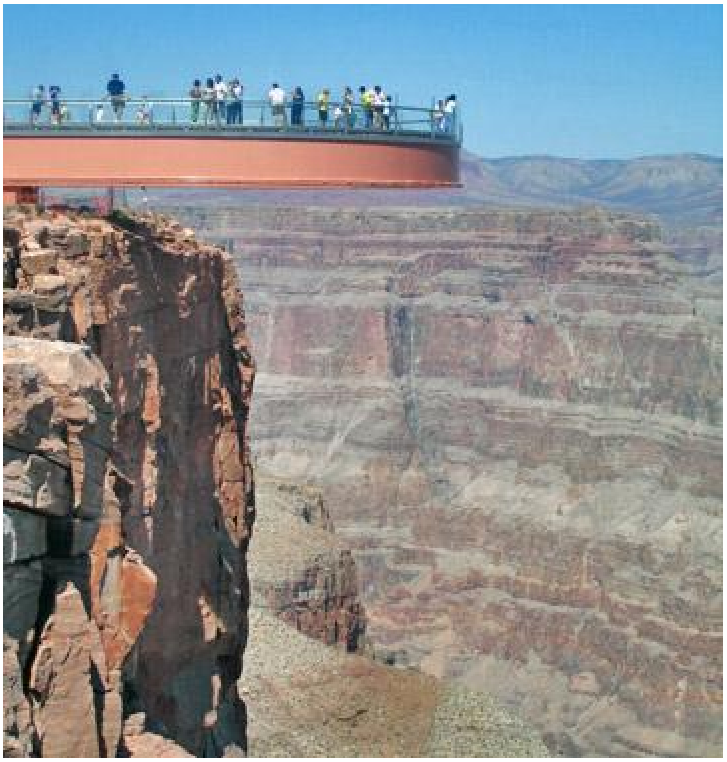
3. Upload your completed document.

Introduction:

The Grand Canyon Skywalk opened to the public on March 28, 2007. This engineering marvel is a horseshoe-shaped observation platform suspended 4,000 feet above the Colorado River on the West Rim of the Grand Canyon. Its crystal-clear glass floor allows stunning views of the canyon below.

Image:

See the following Creative Commons–licensed image to get a sense of the structure.



The Grand Canyon Skywalk from the outside ledge. Image by Complexsimplellc. CC BY 2.5.

Videos: Need more inspiration before starting the project? Check out these videos to marvel at the wonder of engineering the skywalk and the wonder of nature that is the Grand Canyon. In the videos you will be able to see the structure being built and the exposed supports.

- *Skywalk History and Engineering* (2:38)

  Citation: GrandCanyonSkywalk. (2011, October 26). *Skywalk history and engineering* [Video]. YouTube. https://www.youtube.com/watch?reload=9&time_continue=5&v=bbjEFNGgP-Q&feature=emb_logo

- *The Grand Canyon Skywalk* (2:58)

  Citation: Staseman. (2007, March 27). *The Grand Canyon Skywalk* [Video]. YouTube. https://www.youtube.com/watch?time_continue=3&v=BvzlZuWrJNw&feature=emb_log

Critical Thinking Warm-up:

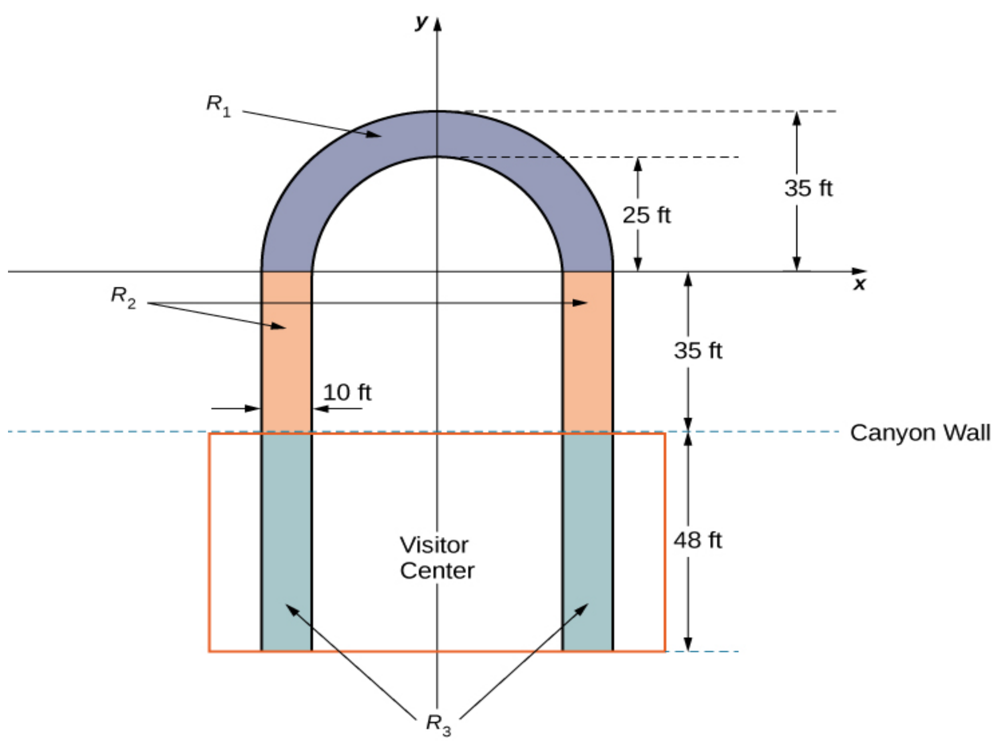
The Skywalk is a cantilever design, meaning that the observation platform extends over the rim of the canyon, with no visible means of support below it. Despite the lack of visible support posts or struts, cantilever structures are engineered to be very stable, and the Skywalk is no exception. The observation platform is firmly attached to support posts that extend 46 feet down into bedrock. The structure was built to withstand 100-mph winds and an 8.0-magnitude earthquake within 50 miles and is capable of supporting more than 70,000,000 pounds.

Explain what a cantilever is (3–5 sentences).

Project Steps:

One factor affecting the stability of the Skywalk is the center of gravity of the structure. We are going to calculate the center of gravity of the Skywalk, and examine how the center of gravity changes when tourists walk out onto the observation platform. The observation platform is U-shaped. The legs of the U are 10 ft wide and begin on land, under the visitors' center, 48 ft from the edge of the canyon. The platform extends 70 ft over the edge of the canyon.

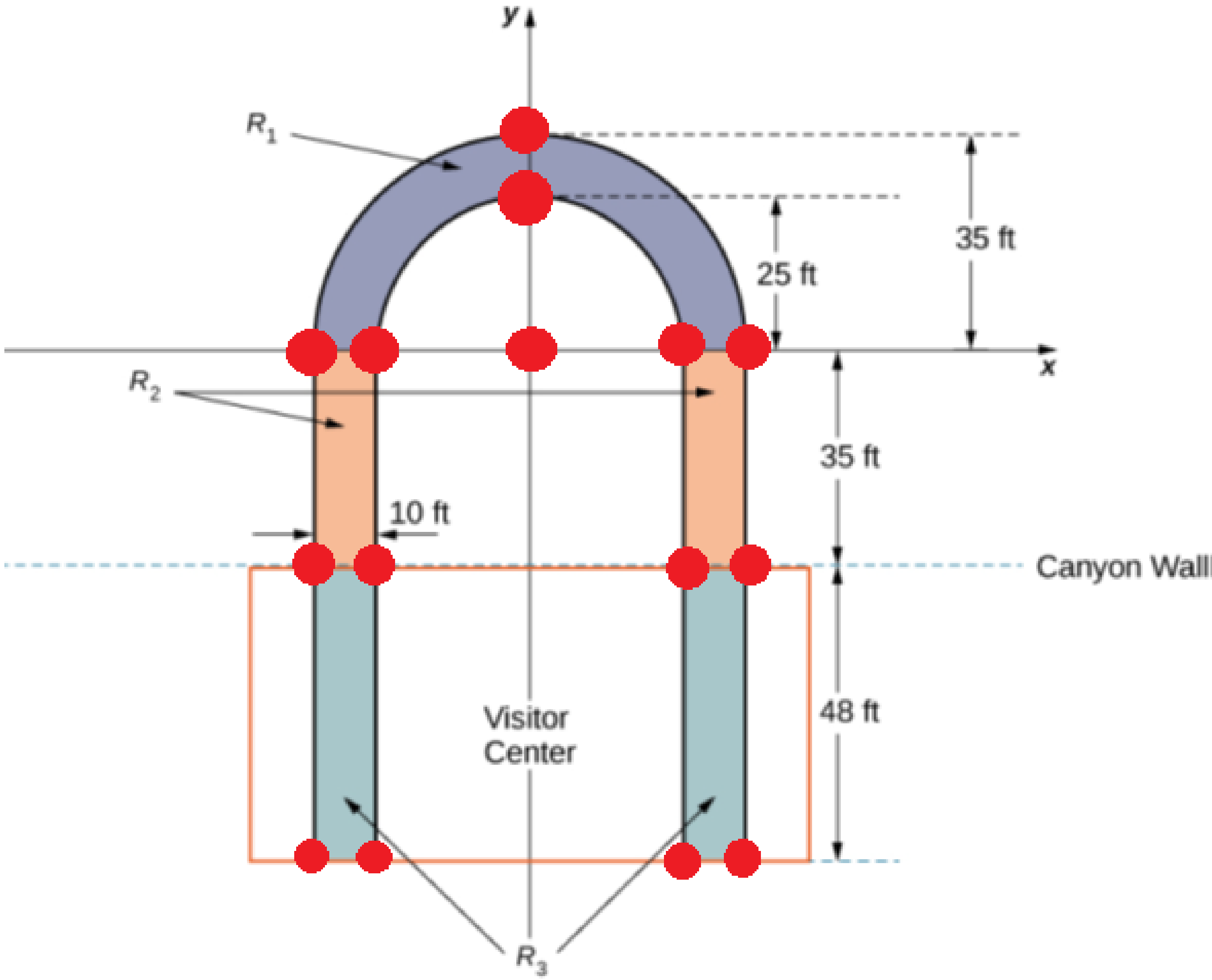
To calculate the center of mass of the structure, we treat it as a lamina and use a two-dimensional region in the *xy*-plane to represent the platform. We begin by dividing the region into three subregions so we can consider each subregion separately. The first region, denoted R1, consists of the curved part of the U. We model R1 as a semicircular annulus, with inner radius 25 ft and outer radius 35 ft, centered at the origin (see the following figure). The legs of the platform, extending 35 ft between R1 and the canyon wall, comprise the second subregion, R2. Last, the ends of the legs, which extend 48 ft under the visitor center, comprise the third subregion, R3. Below is the diagram.



1. Explain, in general, what the term "center of mass" means (1–3 sentences).

2. **Explain what a "lamina" is (1–3 sentences).**

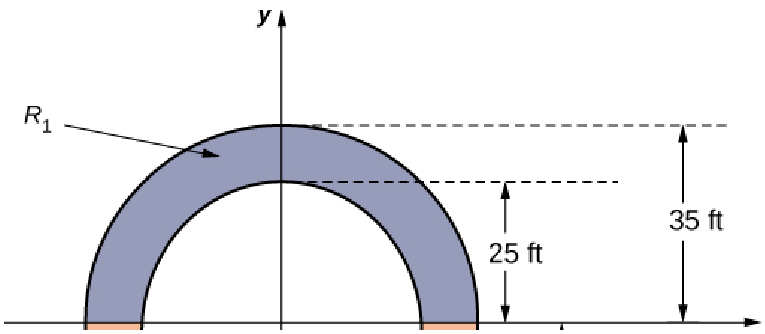
3. **Label the coordinates (x,y) of each point with a red dot on the diagram below. Label the equation of the axis of symmetry. (Use the "insert text box" feature in Word to place the labels next to the appropriate dot.)**



4. **Compute the AREA OF EACH OF THE THREE SUBREGIONS. The subregions form the platform of the structure.**
   - **The areas of regions R2 and R3 should include the areas of the legs only, not the open space between them.**
   - **Type the exact value of your answer below (not a decimal equivalent using BOLD GREEN font.**

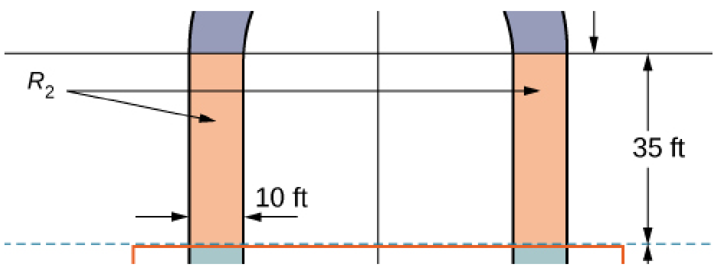
- **Insert a picture of your handwritten work below each diagram. Use these exact values in further calculations.**

a) R1 area =



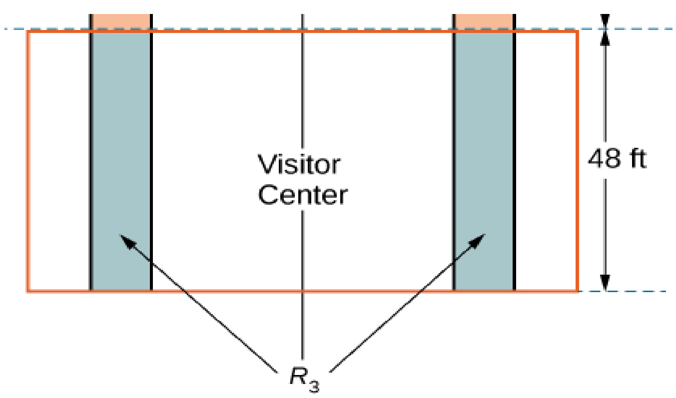
(Insert picture of handwritten work for R1 area.)

b) R2 area =



(Insert picture of handwritten work for R2 area.)

c) R3 area =



(Insert picture of handwritten work.)

Assume the density of the lamina is constant and assume the total weight of the platform is 1,200,000 lbs. (Not including the weight of the visitor center; we will consider that later.)

Hints:

$$accelleration\ due\ to\ gravity:\ g\ =\ 32\ ft/sec^2$$

$$weight\ =\ mass\ *\ acceleration$$

$$mass\ =\ \rho\int_a^b f(x)\,dx$$

$$area\ of\ region\ =\int_a^b f(x)\,dx$$

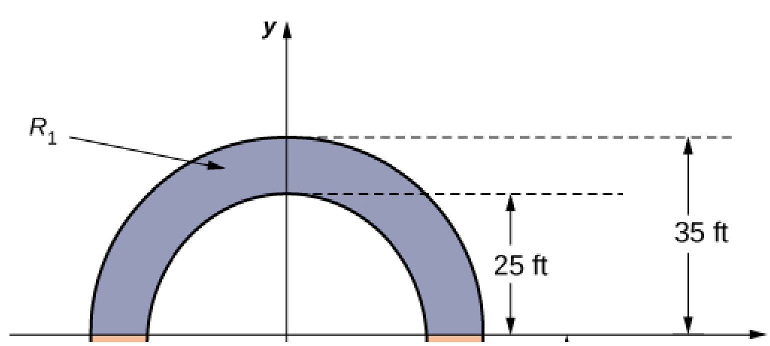
5. **Determine the DENSITY OF THE LAMINA (which is constant for all regions).**
   - **Round your answer to 8 decimal places. Use all 8 decimal places in the remaining calculations.**
   - **Type your answer below using BOLD GREEN font.**
   - **Insert a picture of your handwritten work.**

   density = rho = ρ =

   (Insert picture of handwritten work for density of lamina)

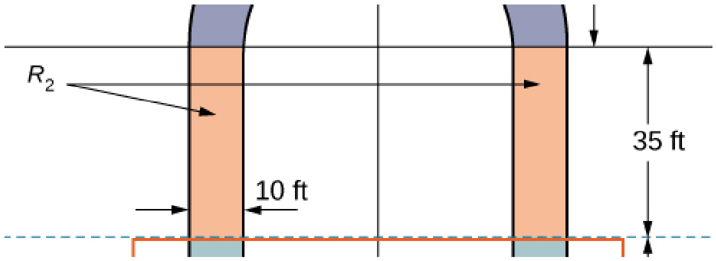
6. **Determine the MASS OF EACH OF THE THREE SUBREGIONS. The subregions form the platform of the structure.**
   - **From physics, the mass of an object is the weight of the object divided by acceleration due to gravity. (Use acceleration due to gravity, g=32 ft/sec^2.)**
   - **Round your answer to the nearest whole number.**
   - **Type your answer below using BOLD GREEN font.**
   - **Insert a picture of your handwritten work.**

   a. **R1 mass =**



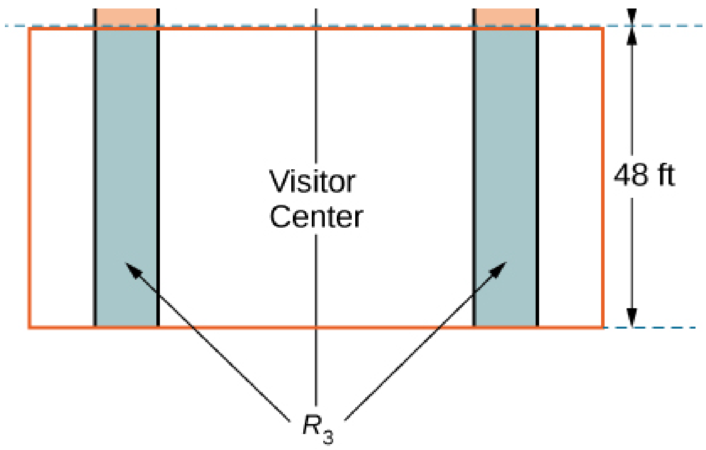
   (Insert picture of handwritten work for R1 mass.)

   b. **R2 mass =**



(Insert picture of handwritten work for R2 mass.)

c. R3 mass =



(Insert picture of handwritten work for R3 mass.)

7. State the *Symmetry Principle* for centers of mass. Refer to the *Moments and Centers of Mass* section of our text.

   (Type the principle here)

8. Calculate the CENTER OF MASS FOR EACH OF THE THREE SUBREGIONS. The subregions form the platform of the structure.

   - Use symmetry when possible. Diagrams are provided below for your convenience.

- **Round your answer to one decimal place.**
- **Type your answer for each region below using BOLD GREEN font.**
- **Insert a picture of your handwritten work.**

a. R1 center of mass =

(Insert picture of handwritten work for R1 center of mass. Insert multiple pictures, as necessary to make the writing easily readable.) You must show the necessary integration to receive credit for the calculation.

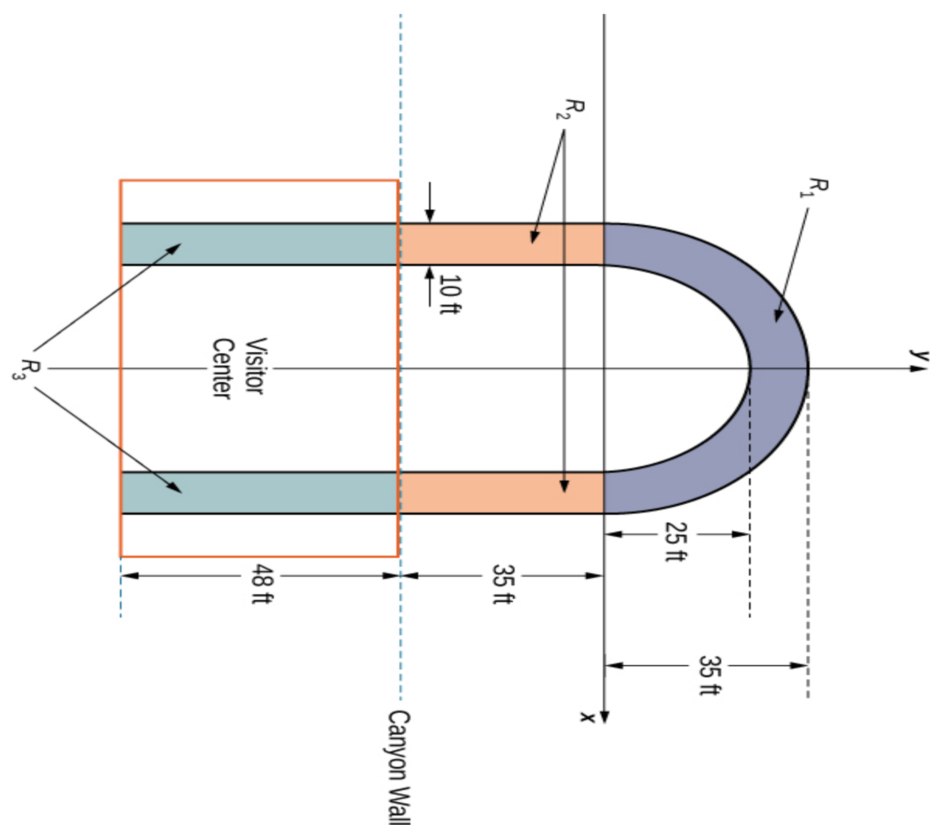
b. R2 center of mass =

(Insert picture of handwritten work for R2 center of mass.)

c. R3 center of mass =

(Insert picture of handwritten work for R3 center of mass.)

9. Label the centers of mass for each region on the following diagram. Label the axis of symmetry. (Use the insert Shape and Textbox feature of Word.)



10. **The centers of mass for each region can be represented by centers of mass of objects (point masses) along a line. State the *Centers of Mass of Objects Along a Line Theorem* from the *Moments and Centers of Mass* section of our text.**

    (Insert a picture of the theorem from the text.)

11. **Now, we will calculate the CENTER OF MASS FOR THE PLATFORM (not including the visitor's center). Treat each of the three subregions as a point mass located at the center of mass of the corresponding subregion.**

    - **Round your answer to one decimal place.**
    - **Type your answer below using BOLD GREEN font.**
    - **Insert a picture of your handwritten work.**

    Center of mass of the platform =

    (Insert a picture of your handwritten work.)

12. **Geographically describe where the CENTER OF MASS FOR THE PLATFORM is located.**

    (Type a description of the geographical location of the center of mass of the platform. One Sentence.)

13. Now we will recalculate the CENTER OF MASS taking into consideration the VISITOR'S CENTER.

- **Assume the visitor center weighs 2,200,000 lbs, with a center of mass corresponding to the center of mass of R3.**
- **Treating the visitor center as a point mass, recalculate the center of mass of the platform including the visitor's center.**

Hint: The total mass is now the mass of the platform plus the mass of the visitor's center.

- **Round your answer to one decimal place.**
- **Type your answer below using BOLD GREEN font.**
- **Insert a picture of your handwritten work.**

Center of mass of the entire platform including visitor center =

(Insert a picture of your handwritten work.)

14. Geographically describe where the CENTER OF MASS including the VISITOR'S CENTER is located.

(Type a description of the geographical location of the center of mass including the visitor's center. One sentence.)

15. Now, we will recalculate the CENTER OF MASS when PEOPLE are on the observation deck. Although the Skywalk was built to limit the number of people on the observation platform to 120, the platform is capable of supporting up to 800 people weighing 200 lbs each. If all 800 people (weighing 200 lbs) were allowed on the platform, and all of them went to the farthest end of the platform, how would the center of mass of the system be affected?

Hint: The total mass is now the mass of the platform plus the mass of the visitor's center plus the mass of the people.

- **Represent the people by a point mass located at the farthest edge of the platform, 70 ft from the canyon wall.**
- **Round your answer to one decimal place.**
- **Type your answer below using BOLD GREEN font.**
- **Insert a picture of your handwritten work.**

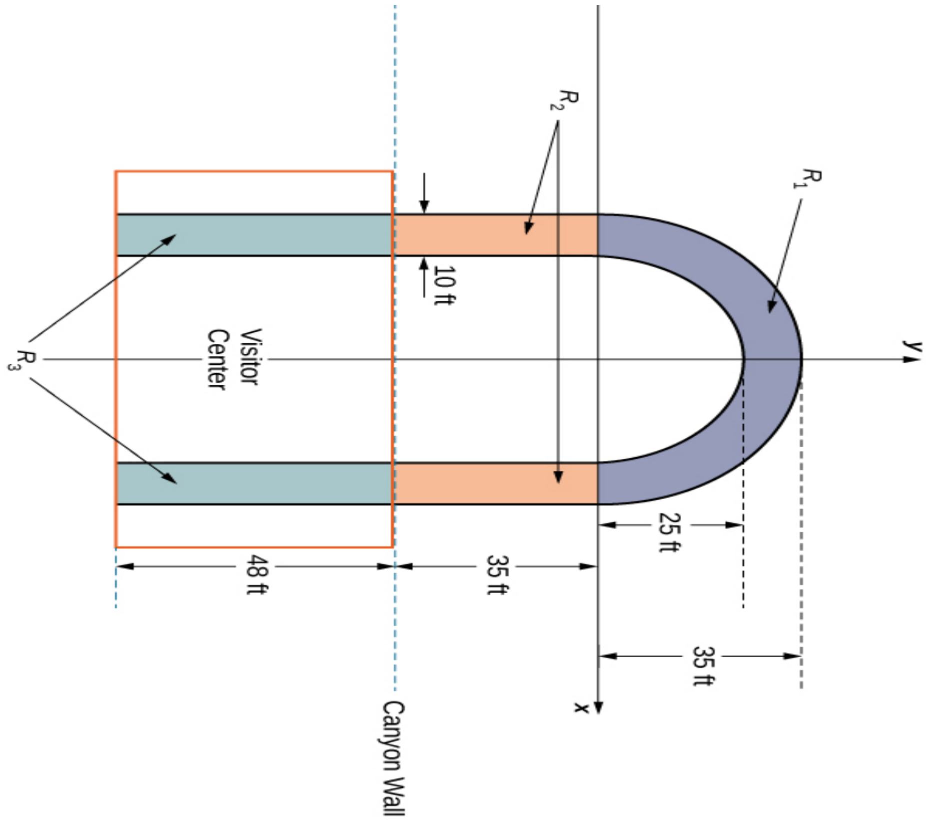
Center of mass of the entire platform including visitor center and people =

(Insert a picture of your handwritten work.)

16. Geographically describe where the CENTER OF MASS when PEOPLE are on the observation deck is located.

(Type a description of the geographical location of the center of mass including thepeople. One sentence.)

17. Label the following centers of mass that we have calculated on the following diagram,
- Platform
- Platform with visitor's center
- Platform with visitor's center and people



18. Prepare a 5- to 10-minute video explaining how to find the center of mass for R1. Include the following:
    a. Smile! An introduction name portion. (State your name)
    b. A time stamp from the calendar on your computer.
    c. Presentation explaining your process and mathematical steps.

19. Questions 1–18 are required components to achieve a C grade on this project (maximum 79%). To achieve an A or B on this project (maximum 100%), ONE of the following two options (a or b) must also be completed.

    a. If you choose this optional step, you will analyze the solutions presented to various integration problems. You will review and complete the [Project 2 Solution Critique] file. For each of the problems, you will need to identify whether the solution presented is correct or incorrect.

    b. Oral presentation and defense of your project via Zoom with instructor (30 minutes): During this time, your instructor will ask you questions regarding your process and calculations in your submitted project.