Application of Integration: Volume

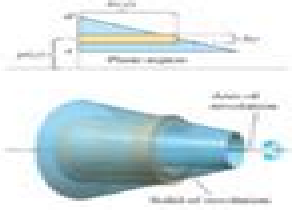
## The Shell Method

To begin, consider a representative rectangle as shown in Figure 7.27, where is the width of the rectangle, $h$ is the height of the rectangle, and $p$ is the distance between the axis of revolution and the center of the rectangle. When this rectangle is revolved about its axis of revolution, it forms a cylindrical shell (or tube) of thickness $w$

Figure 7.27

- The radius of the larger cylinder corresponds to the outer radius of the shell, and
- the radius of the smaller cylinder corresponds to the inner radius of the shell.

$$\begin{aligned}\text{Volume of shell} &= (\text{volume of cylinder}) - (\text{volume of hole})\\ &= \pi\left(p+\frac{w}{2}\right)^2 h - \pi\left(p-\frac{w}{2}\right)^2 h\\ &= 2\pi phw\\ &= 2\pi(\text{average radius})(\text{height})(\text{thickness}).\end{aligned}$$



Consider the plane region in Figure shown is revolved about a line to form the indicated solid. Consider a horizontal rectangle of width $\Delta y$. As the plane region is revolved about a line parallel to the axis, the rectangle generates a representative shell whose volume is

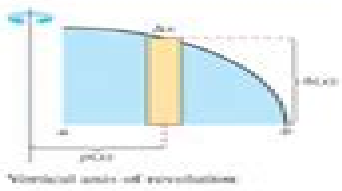
$$\Delta V = 2\pi[p(y)h(y)]\,\Delta y.$$

**THE SHELL METHOD**

To find the volume of a solid of revolution with the **shell method**, use one of the formulas below. (See Figure 7.29.)

| Horizontal Axis of Revolution | Vertical Axis of Revolution |
|---|---|
| Volume $= V = 2\pi\int_c^d p(y)h(y)\,dy$ | Volume $= V = 2\pi\int_a^b p(x)h(x)\,dx$ |

Horizontal axis of revolution

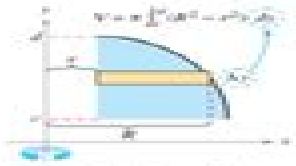


Vertical axis of revolution

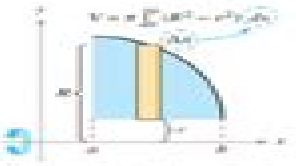
Example:

1. Find the volume of the solid of revolution formed by revolving the region bounded by $y = x - x^2$ and the $x$-axis $(0 \le x \le 1)$ about the $y$-axis.
2. Find the volume of the solid of revolution formed by revolving the region bounded by the graph of $x = e^{-y^2}$ and the $y$-axis $(0 \le y \le 1)$ about the $x$-axis.
3. A pontoon is to be made in shape shown. The pontoon is designed by rotating the graph of $y = 1 - \frac{x^2}{16}$, $-4 \le x \le 4$ about the $x$-axis, where $x$ and $y$ are measured in feet. Find the volume of the pontoon.

## Comparison of Disk Method and Shell Method



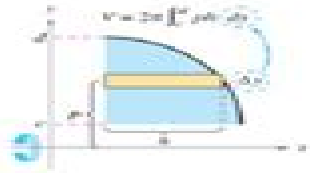
Vertical axis of revolution



Horizontal axis of revolution

Disk method: Representative rectangle is perpendicular to the axis of revolution.

Vertical axis of revolution



Horizontal axis of revolution

Shell method: Representative rectangle is parallel to the axis of revolution.

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# Geometry Integration Application Connection

Richard Bailey

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