Street Math, Space Shuttle Style

Elementary

1. Six standard-weight tanks, 86 lightweight tanks, and 43 super lightweight tanks flew on Space Shuttle missions. Additionally, three tanks were built and used as test articles, including ET-94, but these never flew in space. How many Space Shuttle external tanks were built? How many flew in space?

6 + 86 + 43 + 3 = 138 tanks built; 135 flew in space

2. ET-94 is an example of the second-generation external tank for the space shuttle known as a “lightweight” tank. The original standard-weight tanks weighed a whopping 77,086 lbs. By decreasing the thickness of the aluminum used to build external tanks, the lightweight tank was born, shedding 6,426 lbs from the specification weight of the original. How much did the first lightweight tanks weigh?

77,086 – 6,426 = 70,660 lbs

3. Over time, lightweight tanks evolved and became even lighter in weight, such that one of the last LWTs manufactured, ET-94, weighed in at 65,081 lbs. How much more weight were engineers able to save when they built ET-94 compared to the first LWT?

70,660 – 65,081 = 5,579 lbs

4. The next iteration of external tanks utilized a new type of metal and some new welding techniques to further reduce the external tank specification weight by 6,581 lbs. How much did one of these super lightweight tanks weigh?

65,081 – 6,581 = 58,500 lbs

5. ET-94 will travel through the streets of Los Angeles lying down on a wheeled transporter that lifts the external tank approximately 7 feet off the ground. ET-94 is approximately 153.8 feet in length and 27.6 feet in diameter. How long and how tall will the entire moving structure be as it travels through the streets of Los Angeles? What challenges might be encountered on the move?

153.8 feet long and 34.6 feet tall

Challenges include, but are not limited to overhead power lines, traffic signal lights, signage, and tight turns.

Middle/High School

6. Space Shuttle external tanks are covered in a layer of foam insulation that is only 1-inch thick in most places, but adds 4,823 pounds to the tank's weight. Though the foam's density varies with the type, an average density is about 2.4 pounds per cubic foot. What is the volume of foam used on an external tank?

4,823/2.4 = 2010 cubic feet

7. The first two Space Shuttle external tanks were painted white in an effort to protect the insulating foam from ultraviolet light damage. It was later determined that the foam was not damaged by uv light, but merely changed color from a light tan to orange when exposed to sunlight. The white paint added an additional 600 lbs to the tank. Considering that an average gallon of heavy-duty exterior latex paint weighs approximately 10.53 lbs with 47.8% solids by weight, what is the approximate weight of a gallon of dry paint? Approximately how many gallons of paint were used to paint a Space Shuttle external tank?

10.53 x 0.478 = 5.03 lbs

600/5.03 = 119.28 gallons or 120 gallons

8. Use geometric shape formulas to determine the approximate surface area of the external tank. Considering that one gallon of paint covers a minimum of 250 square feet, do your calculations of the number of gallons used (question 7 above) jibe with the number of gallons required to cover the surface of the external tank? Why or why not? What factors might induce error in your calculations?

Rough over-estimate of surface area of a cylinder = $2\pi rh + 2\pi r^2$ = (2π x 13.8 x 153.8) + ($2\pi(13.8)^2$) ~ 14,500 square feet

More refined surface area estimate, using surface area of a (shorter) cylinder plus surface area of a cone or semi-circle -> Shorter cylinder = 0.8 * 153.8 ~ 123 feet high; Cone height ~30.8 feet =>

$2\pi rh + \pi r(r+\sqrt{(h^2+r^2)})$

(2π x 13.8 x 123) + (π x 13.8)(13.8 + $\sqrt{(30.8^2 + 13.8^2)}$)
~ 10,665 + 2,061 ~ 12,700 square feet

Surface area/250 sq feet per gallon ~ 50-58 gallons

Does not take into consideration possible absorption of paint by foam or multiple layers of paint used.

9. Use the Google Maps “measure distance” function or any distance mapping technology to determine the number of miles ET-94 will travel on the streets of Los Angeles.

Approximately 16 miles

10. It is estimated that ET-94’s trip through the streets of Los Angeles will take 16-18 hours because it has to slow to carefully navigate turns. What is the average speed at which ET-94 will travel? Research: What was the maximum speed attained by an average external tank attached to a Space Shuttle during launch?

A) Approximately 1 mile per hour

B) 17,500 mph

11. Examine the route map for ET-94. Why does ET-94 make a left turn from Fiji Way onto Lincoln (PCH) and take such a roundabout way? Why not turn right from Fiji Way onto Lincoln (PCH)?

It would not fit under the overpass at Culver Blvd. and Lincoln (PCH).

12. ET-94 is 153.8 feet long, has a diameter of 27.6 feet, and will be transported on a dolly that will lift it approximately 7 feet off the ground. A Mack truck will be pulling the dolly which has independent steering on the fore and aft axles. Use the Google Maps “measure distance” function to plot the path of ET-94 as it turns from the Marina freeway onto Culver Blvd. In examining satellite imagery and street views, will ET-94 be able to make the turn without any removal of trees, power lines, or other obstructions? What, if anything, must be removed?

It might make it without moving anything, but it would be a tight squeeze. It would be safest to remove the traffic signal on the inside (southwest) corner.