Mass of “Big Brother” in *2010: Odyssey Two*

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December 27, 2007

Introduction

In his science fiction novel *2010: Odyssey Two*, author Arthur C. Clarke describes a large rectangular slab that has been build by an alien race and placed in orbit around Jupiter. A team of American and Russian astronauts has been sent to Jupiter to investigate the nature of the alien slab, which has been named “Big Brother” by the Americans and *Zagadka* by the Russians.

In Chapter 24 of the novel, one of the astronauts has an idea about how to calculate the mass of the slab, using a shuttle pod called *Nina*:

> “I’ve a suggestion. Take [the *Nina*] to the exact center of the big face. Bring her to rest—oh, a hundred meters away. And leave her parked there, with the radar switched to maximum precision.”
>
> “No problem—except that there’s bound to be some residual drift. But what’s the point?”
>
> “I’ve just remembered an exercise from one of my college astronomy courses—the gravitational attraction of an infinite flat plate. I never thought I’d have a chance of using it in real life. After I’ve studied *Nina*’s movements for a few hours, at least I’ll be able to calculate *Zagadka*’s mass.”

In this paper I will show how the mass of the slab may be determined from information given in the novel.

Solution

We first begin by listing a few facts taken from the novel:

- The slab is a rectangular parallelpiped, whose sides are in the ratio 1 : 4 : 9 (Chapter 23).
- The slab is “more than two kilometers long” (Chapter 23).
- The shuttle pod *Nina* is initially set at rest a distance of 100 meters from the center of the largest face of the slab. (Chapter 24).
- It took 50 minutes for the *Nina* to fall the 100 meters to the surface of the slab. (Chapter 25).
- The astronauts calculate the mass of the slab to be “950,000 tons” (Chapter 25).

We begin the solution by writing down Gauss’s Law for gravity:

$$\oint_S \mathbf{g} \cdot \mathbf{n}\, dA = -4\pi G m \tag{1}$$

(This equation is described in a separate paper, *Gauss's Law for Gravity*.) Here g is the acceleration due to the gravity of mass m, and G is the universal gravitational constant.

Evaluating this equation for an infinite plane using a pillbox surface S (as described in *Gauss's Law for Gravity*), we find the acceleration due to the gravity of the plane is

$$g = 2\pi G\sigma, \tag{2}$$

where σ is the area density (mass per unit area of the plane).

Since the acceleration is constant, we can find the time required to fall a distance x from rest using one-dimensional kinematics:

$$x = \tfrac{1}{2}gt^2 \tag{3}$$

Substituting the expression for g for an infinite plane from Eq. (2), we get

$$x = \tfrac{1}{2}(2\pi G\sigma)t^2 \tag{4}$$

By definition, the density σ is the mass M per unit area A; substituting $\sigma = M/A$, we get

$$x = \frac{1}{2}\left(2\pi G\frac{M}{A}\right)t^2 \tag{5}$$

Solving for the mass M, we find

$$M = \frac{xA}{\pi G t^2} \tag{6}$$

Now we know (or can find) all the quantities on the right-hand side:

- $x = 100$ meters (given).
- We can work out the area A of the large face, since we know the longest dimension is over 2 kilometers, and the sides are in the ratio 1 : 4 : 9. This means that the shortest dimension (thickness of the slab) is (2 km)/9 = 222 meters; the width is (2 km)(4/9) = 889 meters; and the length is 2 km = 2000 meters. Therefore the area of the large face is $A = (889\text{ m})(2000\text{ m}) = 1.778 \times 10^6\text{ m}^2$.
- G is a known universal constant: $G = 6.67428 \times 10^{-11}\text{ m}^3\text{ kg}^{-1}\text{ s}^{-2}$.
- The time required to fall to the surface of the slab from 100 meters is given: $t = 50$ minutes = 3000 seconds.

Making these substitutions into Eq. (6), we find

$$\begin{aligned} M &= \frac{(100\text{ m})(1.778 \times 10^6\text{ m}^2)}{\pi(6.67428 \times 10^{-11}\text{ m}^3\text{ kg}^{-1}\text{ s}^{-2})(3000\text{ s})^2} && (7)\\ &= 9.42 \times 10^{10}\text{ kg} && (8)\\ &= 94{,}200{,}000\text{ metric tons} && (9) \end{aligned}$$

Note that this is a factor of 100 larger than the figure given in the novel ("950,000 tons"); the figure in the novel is wrong.