

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 built 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 parallelepiped, 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:

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

(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

$$g = 2\pi G\sigma, \quad (2)$$

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:

$$x = \frac{1}{2}gt^2 \quad (3)$$

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

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

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

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

Solving for the mass M , we find

$$M = \frac{xA}{\pi Gt^2} \quad (6)$$

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 $(2 \text{ km})/9 = 222$ meters; the width is $(2 \text{ km})(4/9) = 889$ meters; and the length is $2 \text{ km} = 2000$ 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

$$M = \frac{(100 \text{ m})(1.778 \times 10^6 \text{ m}^2)}{\pi(6.67428 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2})(3000 \text{ s})^2} \quad (7)$$

$$= 9.42 \times 10^{10} \text{ kg} \quad (8)$$

$$= 94,200,000 \text{ metric tons} \quad (9)$$

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.