NEWTON'S 2ND. LAW

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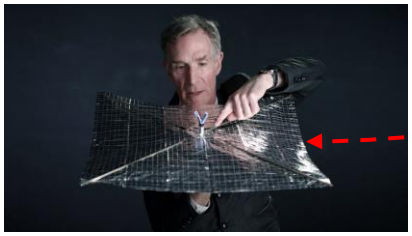
jpcise@austincc.edu & New York Times, Oct. 26, 2017 by Andy Webster

BILL NYE: SCIENCE GUY



Bill Nye has embraced a new mission: educating an older generation on climate change and championing space exploration. In the film "Bill Nye: Science Guy," Mr. Nye, the 1990s children's-television personality with the signature bow tie, warns of "an anti-science movement" afoot in this country. And this delightful, revealing documentary, directed by David Alvarado and Jason Sussberg, offers evidence supporting that assessment.

INTRODUCTION: Purpose of this application is to find the acceleration the lightsail spaceship proposed by the Planetary Society and Bill Nye.
From Newton's second law: **$F_{NET} = m\,a$**
From below: F(90 % efficiency)/A = 8.17 μ N/m.²
σ = area density = mass/area = m/A = 5.27 X 10^{-3} kg./m.² (from below table),

$$F_{NET}/m = a = F/\sigma A = (F/A)/\sigma = a$$

Thus, in the case here: F/A as above, and σ = 5.27 X 10^{-3} kg./m.².
QUESTIONS: (a) Find a of lightsial spaceship?
(b) Find speed (km./s. & mph) after one year? $v_0 = 0$
HINTS: 2236.9 mph/(km./s.), 365 days/yr.
ANSWERS: (a) 1.56 mm/s.²,(b) 49.2 km./s,
Or 110,057 mph , WOW! Quite a sailboat!

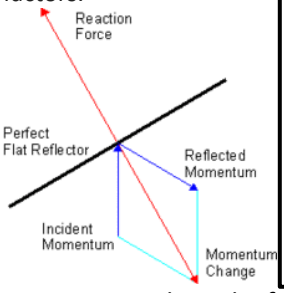
Solar radiation exerts a pressure on the sail due to reflection and a small fraction that is absorbed.

The momentum of a photon or an entire flux is given by Einstein's relation:[14][15]

$p = E/c$ from Einstein: $E^2 = (pc)^2 + (m_0c^2)^2$ but for photons $m_0 = 0$, thus $p = E/c$

where p is the momentum, E is the energy (of the photon or flux), and c is the speed of light. Solar radiation pressure can be related to the **irradiance (solar constant) value of E = 1361 W/m² . For a perfect reflectance: F = 9.08 μN per square metre (9.08 μPa)** in the direction normal to surface (an elastic collision). From momentum conservation concepts: Impulse = $mv_0 - mv$, in this case $v_o = v$, $v = -v$, thus Impulse = 2 m v = 2 p

Thus, force/area **$F = 2p = 2E/c$** , in this case, F = 2 (1361 W/m²)/ 3 X 10^8 m./s. = 907 X 10^{-8} N/m² = **9.07 μ N/m.² = F**
An ideal sail is flat and has 100% specular reflection. **An actual sail will have an overall efficiency of about 90%, about 8.17 μN/m²**,[15] due to curvature (billow), wrinkles, absorbance, re-radiation from front and back, non-specular effects, and other factors.



Force on a sail results from reflecting the photon flux

Graphic A: **p = 2E/c , p/t = 2E/ct, p = F t , note E = energy , thus F t/t = (2E/t)/c , where E/t = power F = (2 Power)/c , note: F & power here is being expressed in units of N/m.² & W(watts)/m.² .**

SOURCES: Information on this page is in upper left from New York Times. The rest is from Wikipedia and crafted(edited) by Dr. John P. Cise.

Sail parameters Sail loading (areal density) is an important parameter, which is the total mass divided by the sail area, expressed in g/m². It is represented by the Greek letter σ. A sail craft has a characteristic acceleration, a_c. Using the value from above of 9.08 μN per square metre of radiation pressure , a_c is related to areal density by: **$a_c = 9.08(\text{efficiency}) / \sigma$ mm/s²** **Assuming 90% efficiency, $a_c = 8.17 / \sigma$ mm/s²** The table presents some example values. Payloads are not included. The first one is from the detailed design effort at JPL in the 1970s. The dimensions for square and lattice sails are edges.

Type	σ (g/m²)	a_c(mm/s²)	λ	Size (km)
Square sail	5.27	1.56	0.26	0.820