NEWTON'S 2ND. LAW: $F_{NET} = ma$

Units 6 & 7 Dr. John P. Cise, Professor of Physics, Austin Com. College, Austin , Tx. , jpcise@austincc.edu & New York Times, Sept. 28, 2017 by Adam Baidawi & Kenneth Chang

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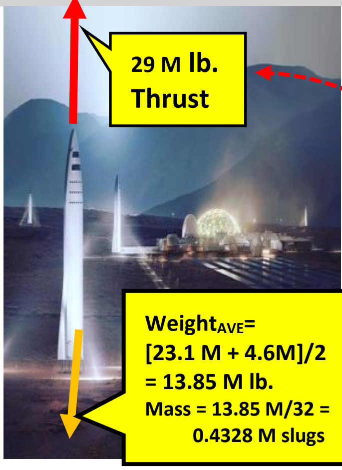
Elon Musk's Mars Vision: A One-Size-Fits-All Rocket. A Very Big One.



29 M lb. Thrust

Weight_{AVE}= [23.1 M + 4.6M]/2 = 13.85 M lb.
Mass = 13.85 M/32 = 0.4328 M slugs

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First stage – ITS Booster	
Length	77.5 m (254 ft)
Diameter	12 m (39 ft)
Empty mass	275 t (606,000 lb)[3]
Gross mass	6,975 t (15,377,000 lb)[3]
Engines	42 Raptor (sea level)
Thrust	128 MN (29×10^6 lbf) sea level 138 MN (31×10^6 lbf) vacuum[3]
Specific impulse	334 s (3.28 km/s) sea level [3]
Fuel	Subcooled CH_4 / LOX
Second stage – Interplanetary Spaceship	
Length	49.5 m (162 ft)

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Second stage – Interplanetary Spaceship	
Length	49.5 m (162 ft)
Width	17 m (56 ft)
Empty mass	150 t (330,000 lb)[3]
Gross mass	2,100 t (4,600,000 lb)[3]
Engines	9 Raptor (6 vacuum, 3 sea level)[3]
Thrust	31 MN (7.0×10^6 lbf) vacuum[3]
Specific impulse	382 s (3.75 km/s) vacuum, for 6 engines 361 s (3.54 km/s) vacuum, for 3 engines[3]
Fuel	Subcooled CH_4 / LOX
Second stage – ITS Tanker	

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Country of origin	United States
Project cost	US$10 billion (before generation of positive cash flow, 2016 estimate)[1][2]
Cost per launch	US$62 million (2016 estimate)
Size	
Height	122 m (400 ft)
Diameter	12 m (39 ft) booster rocket
Width	17 m (56 ft) spaceship or tanker
Mass	10,500 t (23,100,000 lb)[3]
Stages	2

ADELAIDE, Australia — Elon Musk is revising his ambitions for sending people to Mars, and he says he now has a clearer picture of how his company, SpaceX, can make money along the way. The key is a new rocket — smaller than the one he described at a conference in Mexico last year but still bigger than anything ever launched — and a new spaceship. Speaking on Friday at the International Astronautical Congress in Adelaide, Australia, Mr. Musk said he had figured out a workable business plan, although his presentation lacked financial figures to back up his assertions. Mr. Musk has long talked about his dreams of colonizing Mars, and at the same conference last year, he finally provided engineering details: a humongous reusable rocket called the Interplanetary Transport System. But he did not convincingly explain then how SpaceX, still a company of modest size and revenues, could finance such an ambitious project. "Now we think we have a better way to do it," he said Friday. The new rocket and spaceship would replace everything that SpaceX is currently launching or plans to launch in the near future. "That's really fundamental," Mr. Musk said. The slimmed-down rocket would be nine meters, or about 30 feet, in diameter instead of the 12-meter behemoth he described last year. It would still be more powerful than the Saturn 5 rocket that took NASA astronauts to the moon. Mr. Musk called it B.F.R. (The "B" stands for "big"; the "R" is for "rocket.") The B.F.R. would be able to lift 150 metric tons to low-Earth orbit, Mr. Musk said. For Mars colonists, the rocket would lift a spaceship with 40 cabins, and with two to three people per cabin, it would carry about 100 people per flight. After launching, the B.F.R. booster would return to the launching pad; the spaceship would continue to orbit, where it would refill its tanks of methane and oxygen propellant before embarking on the monthslong journey to Mars.

Mars Base Camp spacecraft

Rocket thrust = 7 M lb.

2nd Stage ave. mass = {[4.6 + 0.33]/2}M/32 slugs = 0.07703 slugs

INTRODUCTION: Final Goal of this application is to find speed to Mars of 41 Raptor version of BFR . 4 question (below) steps are needed to that end: **QUESTIONS:** (a) Acceleration of Booster stage(upper left graphic).,(b) Speed at end of 334 second Booster stage. (c) Acceleration of second stage (see graphic at left).,(d) Speed at end of 366 second 2nd stage thrust of 7×10^6 lb. ?

lander that could take astronauts to Mars

HINTS: Thrust fuel loss affects mass size. Thus, in finding mass size during thrust periods (of booster and second stage) average mass will be used. During 334 seconds of booster thrust: $\text{Booster Weight}_{AVE}$= [23.1 M + 4.6M]/2 = 13.85 M lb. **Mass = 13.85 M/32 = 0.4328 M slugs.**, During 366 second 2nd. Stage thrust: **2nd Stage ave. mass** = {[4.6 + 0.33]/2}M/32 slugs **=0.07703 slugs**

Note: 0.33×10^6 lb. is empty mass of 2nd stage, 4.6 M lb. is mass of second stage.

QUESTION REVIEW: (a) Set up working equation first using Newton's 2nd law. Show working equation. Find acceleration of Booster with attached 2nd stage on top ?, (b) Find speed at end of 334 s. Booster stage?, (c) For 2nd stage set up working equation first using Newton's 2nd law. Show working equation. Find acceleration of stage 2 with crew cabin attached on top ?, (d) Find speed at end of 366s. second stage?, (e) Find final speed in mph?

HINTS: $F_{NET} = ma$, $V = V_0 + at$, 88 ft./s. = 60 mph , 0.68 mph = 1 ft./s.

ANSWERS: (a) a = 35 ft./s.^{2}, (b) v = 11,691 ft./s., (c) a =90.87 ft./s.^{2} , (d) V = ~44,949 ft./s. (e) V = ~ 30,565 mph. **COMMENT:** (e) Reasonable speed since escape velocity is ~25,000 mph.