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Calculating the Power Output of Qui-Gon Jinn's Lightsaber

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Abstract
This paper gives a summary of the power output of the standard green lightsaber wielded by Qui-Gon Jinn in Star Wars Episode 1: The Phantom Menace. The power output of a lightsaber was found to be 6.96MW, which dwarfs the output of common construction tools. This power is only two orders of magnitude smaller than that produced by small nuclear generators, showing that lightsabers are effective weapons.

Introduction
The lightsaber is the iconic weapon of the Jedi Knights and Sith Lords of the Star Wars universe. The Star Wars films portray the lightsabers as weapons that can effortlessly cut through different materials. This paper will discuss the power output of Qui-Gon Jinn's lightsaber, based on a scene in Episode 1 – The Phantom Menace (apologies to all Star Wars fans that a prequel film is being used for this model).

Figure 1 - Qui-Gon Jinn cutting through a metal blast door in the Phantom Menace [1].

The calculations themselves are similar to work done on a blog post which will be referred to and cited throughout the paper; however, the accuracy of these calculations and subsequent conclusions will be scrutinised.

Application
In the scene in question, when trying to reach the bridge of the droid battleship, Qui-Gon attempts to melt a hole in a blast door which blocks his route [2]. The lightsaber successfully melts through door, as can be seen from the molten metal oozing from the cut in Figure 1. The energy output of the lightsaber can be calculated using the equation for heat energy:

$$Q = mc_s(T_{melt} - T_0) + mL_f + mc_l(T_f - T_{melt}) \quad (1)$$

This equation relates the heat energy, Q, to the mass of material melted, m, and the change in temperature from initial, T_0, to melting point, T_{melt}, and from melting point to final temperature, T_f. Therefore, in order to calculate the energy produced by the lightsaber the temperature and mass must be estimated. Rhett Allain used the colour of the metal to estimate the temperature it reached [3]. He estimates the temperature to be 5200K (red arrow, Figure 1) – this is 500K less than the Sun's surface temperature, which seems too hot to be reasonable as this temperature could potentially melt the hilt of the lightsaber. He also estimated the unmelted metal temperature to be 2700K (blue arrow, Figure 1), but it appears that he has estimated the 2700K from the melted metal that has oozed out of the cut rather than the unmelted door. Therefore, this is used as the estimate for final temperature as it is the more accurate estimate for the temperature of the melted metal.

The melting point, mass, and associated constants are all dependant on the metal the door is made of. In the blog [3], they fabricate a metal because the Star Wars universe uses metals which are fictional. As the metal is crucial to the equation, fabricating a metal will tell little about the lightsaber itself. As this is occurring on a battleship it is reasonable to assume that the fictional metal used is Doonium [4] - a heavy grey metal commonly used in battleship construction in the Star Wars universe. Comparing this to common Earth metals, it is reasonable to assume that Doonium is similar to titanium or aluminium, which are both used in construction in reality. Aluminium would be used in the calculations if the metal being melted was on the outer hull. Aluminium is commonly used in real spacecraft for its ability to withstand take-off stress as well as being lightweight. Titanium was used for these calculations as the door shown in Figure 1 is a heavy blast door designed to withstand blaster attacks, and thus requires a tougher construction metal.

The mass of titanium melted in the door can be found to be the product of the volume and density of the material. The density of titanium is commonly known to be approximately 4506kg.m^{-3} [5]. The volume of the metal melted is in the shape of a half ring; Figure 2 shows the cross sectional area of the half ring.

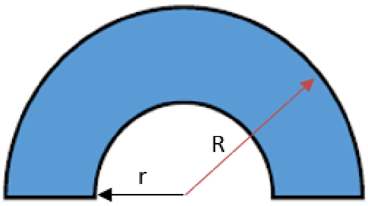

Figure 2 - The cross sectional area of the half ring cut out of the door.

The volume of the melted metal can be calculated using Equation 2:

$$V = (A) \times d \; = \left(\frac{\pi R^2}{2} - \frac{\pi r^2}{2}\right) \times d \qquad (2)$$

Where depth (d) is the width of the door, and A is the cross sectional area of the half ring, as shown by Figure 2. This area is the difference in area between two semicircles with radii R and r respectively (Figure 2). Using the film clip, the width of the door was assumed to be 0.15m [2]. Estimating that the hole Qui-Gon is cutting has diameter 1m, this means that R is 0.5m. Since the width of a standard lightsaber is approximately 0.04m [6], the distance between the inner edges of the hole is 0.92m, and therefore r is equal to 0.46m. Therefore, substituting these values into Equation 2 gives a volume of 9.05×10^{-3} m^3. Using this volume and the density (4506 kg.m^{-3}), the mass of titanium melted in the scene is shown in Equation 3.

$$m = \rho V = 40.77kg \qquad (3)$$

Assuming the door is initially at room temperature, then the variables are as shown below:

T_0 (K)	T_{melt} (K)	T_f (K)	m (kg)
298	1941	2700	40.77
c_S (J.kg^{-1}.K^{-1})	c_l (J.kg^{-1}.K^{-1})	L_f (J.kg^{-1})	
523	790	419000	

Table 1 - Showing, from left to right and up to down; Initial temperature, melting point, final temperature, mass, solid specific heat capacity [5], liquid specific heat capacity [7] and latent heat of fusion [8].

Substituting the values from Table 1 directly into Equation 1, the heat energy is found to be 76.56MJ. The power output of the lightsaber is the ratio of this heat energy to the time it takes to melt through the metal. Allowing for continuity errors in filming it was estimated from the clip [2], that Qui-Gon took 11s to melt through the blast door, therefore:

$$Power = \frac{Energy}{Time} = \frac{76.56MJ}{11s} = 6.96\ MW \qquad (4)$$

This means that the power of the standard green lightsaber that Qui-Gon uses is 6.96MW. This is a large power output for a small tool compared to mundane tools; for example, a circular saw requires just 2kW to start [9]. Small nuclear generators have a power output of 500MW [10]; this is only two orders of magnitude greater than the power of a lightsaber. This suggests the lightsaber has an efficient power source in the fictional Star Wars Universe in comparison to real world power sources, as it produces an exceptionally large amount of power from a comparatively small source.

Conclusion

The lightsaber is a highly efficient weapon in the Star Wars Universe, with a power output of 6.96MW. This dwarfs the power output of common construction tools, and is only two orders of magnitude smaller than the power output of small nuclear power generators. This high power output means that there is a lot of energy being pumped into the material in a short space of time. This high output from such a small source is what makes the lightsaber such an efficient tool for cutting through dense materials and battling droids.

References

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