I. Introduction

Try punching someone in real life. I would bet quite safely that your victim would NOT be sent flying back at a supersonic speed. Yet for a video game, I would retract my bet immediately. Superheroes in video games, just like those in movies, magazines, and books, are not bound by the laws of physics—after all, who would buy a super-realistic game whose environment is exactly the same as that of real life? Even games that work hard to emulate real life must have compromises between reality and feasibility, between reality and creativity, between reality and fun. But the vast majority of games do not try to blindly stick to realism. Sure, most games try to imitate the very basic laws of physics, namely gravity, momentum, and energy, but do not try to implement them exactly. This essay is an investigation on just which rules are violated, to what extent, and to what effect, in the Nintendo Wii game Super Smash Bros. Brawl.¹ In particular, I am going to examine a certain special combat move in the game known as the Falcon Punch.

¹ Super Smash Bros. Brawl is copyrighted under Nintendo.
The Falcon Punch is the signature move of character Captain Falcon. It is a slow, deliberate, charged-up move that uses the full swing of the body, delivering an incredible amount of force. When rendered in *Super Smash Bros. Brawl* (SSBB), however, the move would not belong in a stereotypical real combat scene. The primary reason is that Captain Falcon’s right hand—most superheroes are right-handed, and Captain Falcon is no exception—actually bursts in flame during the swing, creating a fiery falcon that appears to add power to the punch.

As shown by the screenshot (“Falcon”), at the end of the move the right arm is fully extended, and Captain Falcon is in a forward lunge position. The lunge indicates a greater distance with which the right fist had to move, and thus a faster punch. Moreover, the target character, Luigi in this case, is knocked into the air, and at a ridiculous speed (not shown on image—currently it is unfeasible to attach a moving video to physical paper, so the image will have to do for now). All this is not to mention that the scene takes place entirely in space, which does not have vital oxygen.
I apologize for my observations so far, which have been broad and unfocused, but I felt it was necessary for you, the reader, to have a basic background in what the Falcon Punch was before proceeding into a more advanced discussion.

II. The Physics of the Falcon Punch

We should first be reacquainted with the basic laws of physics that deal with motion and energy. The most important law we have is the *conservation of energy*, which states more or less that energy is not created or destroyed—it is transformed. To give an example it would be easier for me to define two more terms: *kinetic energy*, the energy imparted by the motion of an object; and *potential energy*, the energy contained in an object at rest. That is to say, a moving baseball has more energy than a nonmoving one, because the moving one has all the same potential energy plus some kinetic energy that the nonmoving one did not have. But what happens when a baseball is caught by an outfielder—does the kinetic energy simply vanish? No, says the law of conservation of energy. This kinetic energy is partially converted to heat, and also has impact on the outfielder’s glove, which further moves the outfielder’s hand, and then his arm.

The formula for kinetic energy of a moving object is

$$KE = \frac{1}{2}mv^2$$

This states that the kinetic energy (KE) of an object is equal to one-half times its mass (m) times its velocity (v) squared. That is, doubling the velocity of an object quadruples its kinetic energy. Now the real implication of the law of conservation of energy in our case is that, in order for a target to be launched back at sound-breaking speeds, there must have been something which supplied that huge amount of energy.
How much energy exactly? The direct approach does not work here because of the variety of weights of the SSBB characters, making it would futile to determine an “average” mass. We shall instead consider the two extremes that have known weights: Jigglypuff at 5.5 kg and Charizard at 90.5 kg (Bulbapedia). A Falcon Punch is capable of launching a weakened enemy at speeds exceeding 3600 mph according to the game screen itself, and because there are a large number of miscellaneous effects that can increase this number, we shall use this as a minimum estimate for the speed. The unit miles per hour is somewhat random, and we must convert it to meters per second—the conversion factor of 0.447 from mph to m/s gives 1609 m/s.

Now we use the formula to find the kinetic energy of the attack, and find that the energy for Jigglypuff is

\[ KE_{\text{Jigglypuff}} = \frac{1}{2}mv^2 = \frac{1}{2}(5.5)(1609)^2 = 7.12 \times 10^6 \text{ J} \]

And for Charizard,

\[ KE_{\text{Charizard}} = \frac{1}{2}mv^2 = \frac{1}{2}(90.5)(1609)^2 = 1.17 \times 10^7 \text{ J} \]

Next we’ll need the physics involved in a punch, which gets immediately more complicated. First we look at force, which is determined by Newton’s second law: F = ma, or force = mass × acceleration. Also important is impulse, which is force multiplied by time, and is significant because “momentum is a conserved quality” and impulse is simply the change in momentum (Chananie). Just like the law of conservation of energy, there is a law of conservation of momentum.

Momentum is defined as

\[ p = mv \]

That is, momentum (p) equals mass (m) times velocity (v). It should be noted that momentum and kinetic energy are both defined in terms of mass and velocity, and momentum is always
conserved. Kinetic energy can sometimes be conserved, but only in certain types of collisions, and this will not be applicable in combat physics (Viegas).

Now we shall calculate the momentum balance of the punch. Because the total momentum before the punch must be equal to the total momentum after it, $m_1v_1 = m_2v_2$. But we also know that during the energy transfer, i.e. when the puncher’s hand is in contact with the target’s body, the hand and body must be moving at the same speed. Thus we have the refined formula, $m_1v_1 = (m_1 + m_2)v_2$, which can be used to estimate the initial velocity that Captain Falcon’s hand requires (“Punching Physics”).

Also according to the “Punching Physics” article the arm is generally 10% of the total mass of the body. We do not have an exact mass for Captain Falcon, but we’ll assume he weighs the standard 70 kg human and thus his arm 7 kg. We rearrange the formula to

$$v_1 = \frac{(m_1 + m_2)v_2}{m_1}$$

For Jigglypuff this gives $v_1 = 2900$ m/s, and for Charizard, $v_1 = 22,000$ m/s. Needless to say, this is quite fast. The Falcon Punch requires 52 frames to charge, and assuming the standard 24 frames per second screen refresh rates on television screens, this would mean that against Charizard, who provides a more interesting analysis, Captain Falcon’s hand must go from 0 to $22\ km/s$ in 2.2 seconds. This means an average acceleration of $10\ km/s^2$, which in turn requires a force of 70,000 Newtons.

The typical superhero—not the typical human!—has a punching force of 200 pounds (Kakalios 89), which is converted to 890 Newtons. Thus Captain Falcon has a punching force that is $\frac{70,000}{890} = 79$ times greater than that of the average superhero.

Of course, there could be other sources of energy as well as that from Captain Falcon, but this is where the laws of physics reach and extend past their modern boundaries.
III. The Anti-Physics of the Falcon Punch

I stated earlier that the law of conservation of energy would be the most useful here. The physically correct method in the previous section determined a punching speed of over 22 kilometers per second, and this is obviously impossible. So, common sense tells us there is another source of energy. After all, the punch does create a flaming falcon out of nowhere. That presumably requires energy too.

Certainly if Captain Falcon had some sort of explosive attached to the front of his fist, he would have a great deal more energy. For example, if such a device could release say $1.1 \times 10^7$ J of energy against Charizard, then Captain Falcon’s hand would not need to go nearly as fast as 22 kilometers per second, though it would still need to move quite fast. But only a very large conventional bomb would have that much energy, and it is empirically known that Captain Falcon does not have any visible attachment on his glove, so whatever device he has must store energy very compactly. There are two such ways to store energy this compactly: nuclear and antimatter (Kaku 165). We can quite safely assume that it is antimatter, which gives up to 1000 times more energy than nuclear power for the same mass of fuel from full conversion of mass into energy via $E = mc^2$, because of what happens in a video involving the Falcon Punch. This video is actually not of a SSBB game, but rather of $F$-Zero, the game in which the character Captain Falcon debuted. In the video, which shows one of the most climactic scenes of the game, the Falcon Punch creates a clearly visible explosion even from the point of view outside the galaxy, and it looks like 100 supernovas happened. This is explainable only by a very condensed energy source held by Captain Falcon—antimatter.
Also interesting aspect is the lack of oxygen, and more generally, the lack of an atmosphere. This seems to invalidate three things, two of which are related to physics. The other is biological, in that Captain Falcon, like any other human, should not be able to survive in space without some kind of air helmet. The first physics violation is similar, in that sound waves cannot travel in space due to the lack of a medium, so the yelling of “Falcon Punch!” should not be heard, unless he is extremely loud. Furthermore, the punch itself cannot create a falcon out of fire, because fire requires oxygen to burn, and there is not enough oxygen in space.

The Falcon Punch is thus a highly unphysical move. It would be near impossible to reconstruct in real life. Even if there was an explosive that provided the bonus force, how is the puncher protected from it?

**IV. Concluding Remarks**

The Falcon Punch is, of course, in a video game, and we would not expect such a move to follow the laws of physics. But there is something special about it, something that we can learn, something that we can hopefully utilize in the near future. It is the nature of simulation, in that the future will contain for us very delicate simulation of reality that will eventually be realer than our outside lives. But simulations are not based on the laws of physics, and even if they try, they only model them and approximate them. A video game, as in the case of *Super Smash Bros. Brawl*, is essentially a simulation designed for entertainment. With entertainment and simulation combined in such an informal manner, we have purposeful adjustments to physics, and after playing the game, we are led to thinking that punching someone really hard will send them flying back at rocket speeds.
I am by no means trying to blame the video game industry for something it is not doing. As a creative art, games will always include human imagination, and just as books are written in the fantasy and science fiction genres, simulations will be produced that intentionally create dream worlds. Perhaps it is futile to simulate the world perfectly, perhaps a close match is all that is needed. After all, we won’t care that we punch our targets correctly, we’ll just care how far they fly.
Works Cited


Bibliography


