HOLLYWOOD BLOCKBUSTERS
Unlimited Fun but Limited Science Literacy
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1 Introduction

There is no doubt that Hollywood has become an established major source for entertainment in the lives of the citizens of the modern society. In the products of Hollywood (big screen movies, TV mini series, TV series, sitcoms, etc) amazing feats are presented by people supposedly the best in their fields. Great scientists find solutions to major scientific challenges, the best NASA employees save the Earth from the ultimate heavenly threats, the best soldiers defeat armies on their own, the best psychics solve criminal cases, the best parapsychologists manage to successfully investigate supernatural phenomena and so on. And of course we should not forget the laypersons who often save the day by finding solutions that scientists could not think of. Unfortunately all this is only great entertainment. When logic and science are used to decide if certain scenarios are consistent and plausible, usually the results are disappointing. The inconsistencies of the Hollywood products with science may come as a surprise to many people who simply accept what they see as realistic or, at worst, slightly modified from reality.

In this article, we will examine specific scenes from popular action and sci-fi movies and show how blatantly they break the laws of physics, all in the name of entertainment, but coincidentally contributing to science illiteracy. Towards this goal, we assume that our reader has an understanding of algebra-based general physics.

2 Cinema Fermi Problems

Fermi problems (also known as back-of-the-envelope problems) 1 have been very popular among physicists 2 since Fermi used them to illustrate his dramatic and extraordinary ability to give approximate answers to the most esoteric and puzzling questions. In a simple adaptation of the idea, we have applied it to plots and particular events appearing in Hollywood movies 3, 4 to help us decide the plausibility of the plot or the event. Often such an analysis is not necessary because the impossibility of the action can be explained qualitatively. Such scenes are those presented in sections 2.1, 2.2, 2.3, 2.4, 2.5. However, some simple calculations reveal additional absurdities.

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2.1 Ignorance of Projectile Motion

In the movie Speed, a bus that has been booby-trapped should not drop its speed below 50 mph, otherwise a bomb will explode killing everyone on board. As the bus is moving on a highway, the people on the bus are informed that, due to road construction, a bridge in the highway is missing its center segment. Unable to stop the bus, the decision is made to jump over the gap. The bus then accelerates to almost 70 mph and, of course, successfully makes the jump.

Figure 1: The gap in the highway in the movie Speed. Notice that the bridge is perfectly horizontal.

The movie gives us several shots of the gap in the highway. The viewer can clearly see that the highway is level at the bridge. Unfortunately, this predetermines the destiny of the bus: there is no way that it will jump over the gap. As soon as it encounters the gap, the bus will dive nose down to hit the ground below the bridge.

At least, the director and the special effects team seem aware of the above fact. So, upon looking carefully at the scene, we see the bus depart from the highway at an angle of about 30° relative to the horizontal. Of course, this is evidence of a miracle as it would happen only if a ramp had been placed exactly before the gap. In the movie, as the protagonists talk to each other, a laughable explanation is given: ‘the road leading to the bridge is uphill’.

In any case, given the miracle, the scene is still problematic. Paying attention to the details of the scene, it looks as if the back end of the bus drops a little after it is over the gap. Probably this is not something the director wanted to show; it may be a remaining flaw from the special effect used to create the scene. However, there seems to be another serious problem: the director shows that, although the bus has tilted upward at an angle, it then flies over the gap in a straight horizontal line! Unfortunately, it is not very easy to verify the trajectory of the bus as the director does not show the whole jump; there are hints in the scene pointing to either

\[\text{Time: 1:05:03–1:06:41}\]
Figure 2: Left: A car (or bus) going over a bridge gap with horizontal initial speed will dive nose down the bridge as soon as it is over the gap. (Picture from [6]). Right: If the initial velocity of the car (not the car!) has a tilt \( \theta \), the car will follow a parabolic path that, depending on the magnitude of the velocity and the tilt, may be long enough to allow the car reach the other side of the bridge.

Figure 3: A sequence of stills as the bus in *Speed* jumps over the bridge gap.

interpretation\(^4\): an incorrect horizontal trajectory and a curved trajectory.

Of course, the jump over the bridge is an example of projectile motion with initial speed \( v \) and initial angle \( \theta \). The bus’s path, like any projectile, must be a parabolic one with its peak at the middle of the gap if the speed and angle are such that the bus will just make it over the gap. If the initial speed and angle are more than enough, then the peak of the path may be shifted towards the the right.

\(^4\)Just watch the clip in slow motion carefully to reach your own conclusion.
Ignoring frictional and drag forces, for a projectile motion the range would be

\[ R = \frac{v^2 \sin(2\theta)}{g} \]

Given the movie data (angle \( \theta = 30^\circ \), speed \( v = 70 \text{mph} = 31 \text{m/s} \) and that \( g = 9.8 \text{m/s}^2 \), this formula implies a range of 85.5 meters. Since the situation seen in the movie must include frictional and drag forces, we may approximate roughly the range of the bus at full speed at 40 meters or about 131 feet. This is less than half the ideal range; usually the range will not be reduced so drastically. So, given the miracle that not only the bus will tilt but, also the velocity vector will tilt at an initial angle of 30 degrees, the bus can jump more than 130 feet. However, the gap is only 50 feet as we are told in the movie. So, the bus should have landed much further on the other side, at least the length of the bus beyond the edge, and not close to the edge of the gap as shown.

### 2.2 Ignorance of Newton’s Laws

In Spiderman [7] the villain Green Goblin kidnaps Spiderman’s girlfriend Mary Jane (M.J.) and takes her on the tower of the Queensboro bridge. There, while waiting for Spiderman, he cuts loose the cable that supports the tramway cabins, which commute between Manhattan and Roosevelt island, and takes hostage a tramway cabin that is full of children. When Spiderman shows up, the Green Goblin is holding in one hand the cable that supports the cabin with the children and M.J. in the other hand.\[5\]

\[\text{Figure 4: Left: Green Goblin in static equilibrium while he holds M.J. and the cabin. Right: A close-up of Green Goblin’s static equilibrium position.}\]

There are some problems with this scene (and its continuation as shown in the movie). Notice in the left still of figure[7] that the cable has the shape of a nice smooth...
curve even at the point where the car is located. If a heavy object is hung from a flexible rope, then at the point of the rope where the object is attached we should see a ‘kink’—that is, a sharp point where the curve is not smooth anymore. However, at another close-up view, the director does show the kink. (Figure 4.) It is possible that the kink in the still of figure 4 is hidden due to the angle the still is taken (so we will not hold this against the director).

![Figure 5: Close-up of the trapped cabin with the children.](image)

In the left still of figure 4, it appears that the left end of the cable is anchored at a higher location relative to the position of the Green Goblin (who is standing on the top of the bridge tower). This would imply that the cabin should slide down the cable towards the Green Goblin. However, in the still of figure 5 it appears that the two ends of the cable are at the same height. Again, we may assume that the illusion in the first still might be due to the angle the still has been taken. On the other hand, if we look at the construction data for the bridge and the Roosevelt Island tramway, we discover that a stretched cable between the top of the bridge tower and the tramway towers cannot be horizontal. In fact, Green Goblin is located at a much higher point. The height of the bridge tower above water is 350 feet while the tramway, at its highest point, is 250 feet above the water.

For the present purposes, we will ignore these technicalities and assume that the two ends of the cable are indeed at the same height. Furthermore, to simplify the math, we shall assume (although not an essential assumption in the calculation) that the cabin has been trapped at the midpoint of the cable. The latter assumption implies that the two forces $\vec{F}_1$ and $\vec{F}_2$ from the cable on the cabin (see figure 5) are equal in magnitude—say $F$. From figure 5 we see that the angle the cable makes with the horizontal is $\theta = 7^\circ$. Then

$$2F \sin \theta = W,$$

where $\vec{W}$ is the total weight of the cabin.
Figure 6: The relevant forces for the scene. Left: The free body diagram for the cabin. Right: The free body diagram for the Green Goblin. The sum on the two normal forces $N_1$ and $N_2$ at the feet of the Green Goblin is equal to the total normal force $N$ as used in the text.

The following forces are acting on the Green Goblin: (a) a force $\vec{F}_3$ from the cable. Since the cable is in equilibrium, the tension along its length is equal to $F$ and thus this is the magnitude of $\vec{F}_3$; (b) a downward force $m\vec{g}$ equal to M.J.’s weight that is acting on his left hand; (c) his weight $M\vec{g}$; (d) the normal force $\vec{N}$ from the tower pointing upwards. In the vertical direction, the forces $+mg$, $+Mg$, $-N$, and the component $+F\sin\theta$ of $\vec{F}_3$ cancel out:

$$mg + Mg + F\sin\theta - N = 0.$$ 

However, there is no force to cancel the horizontal component $F\cos\theta$ of $\vec{F}_3$. This implies that the Green Goblin—no matter how strong he is—cannot stay in static equilibrium.

One can try to save the situation by claiming that a static frictional force $\vec{f}_s$ must also be in operation. Indeed, in this case the forces seem to cancel in the horizontal direction too:

$$F\cos\theta - f_s = 0.$$ 

However, Green Goblin still cannot stay in static equilibrium. Given that the maximum value of static friction is $\mu_sN$, cancellation of the forces requires that

$$\mu_s \geq \frac{W}{2 \tan\theta (W/2 + Mg + mg)}.$$ 

The cabin’s weight is much bigger than the combined weight of M.J. and the Green Goblin. So, $W/2 + Mg + mg \simeq W/2$ and therefore

$$\mu_s \geq \frac{\cot\theta}{2} \simeq 4.$$
Coefficients of friction are usually below 1. In some exceptional cases they can be higher than 1 but a coefficient of 4 is extremely high and probably attainable only if the materials in contact have adhesive properties. Besides the fact that it is not easy to obtain the high value of friction necessary, even if we did have it, the two forces \( \vec{F}_3 \) and \( f_s \) would act at different locations and would create considerable torque that could not be matched by the opposing torque created by \( m\vec{g} \).

### 2.3 Ignorance of Impulse

Aeon Flux is a rebel assassin with superhero capabilities. She is working for the Monicans, a group of rebels trying to overthrow the government. She is sent on a mission to kill the Chairman, the head of the government. Assisted by Sithandra, Aeon is trying to reach the government’s building that is surrounded by a booby trapped field. In an effort to defeat the defensive system that monitors the field, Aeon uses her gymnastic abilities. She displays a series of cartwheels and summersaults. In one of such display, as she lands she notices that sharp blades are coming out of the grass. To compensate, as soon as she lands her feet on the stone boarder of the grass, she stops her forward movement by arranging her body in the position shown in the left picture of figure 7. Although her body comes close to the blades, she never touches them, thus escaping a fatal encounter.

![Figure 7: Left: Aeon Flux’s life saver landing position. Right: Aeon Flux’s feet at the previous position.](image)

All this might excite the audience of the movie and, and especially the sympathizers of the heroine, but the scene is ridiculous. As Aeon Flux lands, she has forward (and downward) momentum. To change it, she needs to be acted upon by an external impulse. The ground certainly can stop her downward motion. However, there is nothing that can stop her forward momentum—well, except the frictional force at the feet of Aeon. If such frictional forces exist, they create torque that reinforces the torque created by Aeon’s weight forcing her to rotate and drop on the sharp blades...
Even if Aeon could magically stop her forward motion and place herself in the position shown in the left still of figure 7, this position is not an equilibrium position at all. As long as her center of mass is not above the line defined by her two feet, the torque created will force her to drop on the grass. Her center of mass is somewhere in her waist; it is evident from the figure that it is certainly not above the line joining her feet.

In an effort to exaggerate the abilities of Aeon, the director makes things worse for himself. He shows to us a close-up view of the way Aeon is standing on the stones. The stones defining the border of the grass are cut with a slope—each stone looks similar to an inclined plane. At the same time the stones have been placed to make a V-shaped border. This configuration makes obtaining equilibrium a really difficult task.

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Figure 8: Sithandra helps Aeon restore her balance. Look at the stones at the lower right side to see clearly the way they are cut.

In order to be fair, we should make the following comment. Internal forces, although they always add to zero, can create a net torque. So, in principle, Aeon’s muscles can create the necessary torque to stop her fall to the grass. Since she is a superhero, we can imagine that she has this ability. It is thus not the way she stands still, but the way she flexes her muscles that keeps her in equilibrium.

2.4 Ignorance of Buoyancy

Hollywood has produced many silly movies whose plot does not make any sense. But only few of them are as awful as The Core. Due to military experiments, the

\[ \text{Of course, if this is the case, it is not easy to explain why she needs Sithandra’s help to rotate her body back to the vertical position as her muscles can push her back. One must assume that the position she has acquired uses the maximum torque her muscles can generate. But then, as she lands she cannot stop her fall since she has initial angular momentum due to her motion and thus her muscle needs to exceed the amount of torque they apply on equilibrium... Well, as our students say, stop thinking...} \]
outer core of Earth has stopped rotating thus leading to a dramatic drop in Earth’s magnetic field that protects Earth from harmful radiation. A team of gifted scientists and pilots is assembled to drive an innovative subterranean vehicle to the core so that, with the help of a nuclear bomb, they may restore its rotation. As the team descends, at a depth of 700 miles, the vehicle crashes in an underground cave. After repairing the damage, one member of the team is killed by flying debris and his dead body drops in lava where it sinks in few seconds.\footnote{Time: 1:09:58–1:10:45}

![Image](image.jpg)

Figure 9: A sequence of stills as a body sinks in lava.

We could discuss many questionable issues with the scene: (a) Could a cave exist in such depths? (b) Could the crew afford to open and close the door of the vehicle in such a depth? This would mean loss of breathable air from the vehicle and changes in the air pressure and temperature of the vehicle. (c) Could the flexible suits that the crew is wearing really protect them at that depth? Many more questions could be added in this list. The reader can reflect on these issues on his own. We will only discuss the sinking of the human body in the lava.\footnote{For the interested reader we point out that an additional cinema Fermi problem based on the plot of The Core can be found in \cite{4}.}

Let’s study what happens to an object that is thrown to the pond of lava. Two forces are acting on the object. First, there will be the force of gravity acting on the object:

\[ F_{\text{gravity}} = g_{\text{below}} M_{\text{object}} \]

where \( M_{\text{object}} \) is the mass of the object and \( g_{\text{below}} \) is the acceleration of gravity at the location of interest. The latter is actually weaker than that on the surface of Earth since—according to a well known theorem of Newtonian gravity—only the material of the Earth located in the sphere below the current depth will contribute to the gravitational attraction:

\[ g_{\text{below}} = G \frac{M_{\text{below}}}{R_{\text{below}}^2}, \]

where \( M_{\text{below}} \) is the mass of the Earth contained in the corresponding sphere. Assum-
ing that the Earth has uniform density, \( M_{\text{below}} = \frac{4}{3} \pi R_{\text{below}}^3 \rho_{\text{Earth}} \). Therefore

\[
g_{\text{below}} = \frac{4\pi G}{3} \rho_{\text{Earth}} R_{\text{below}}.
\]

In the same way, the acceleration of gravity \( g = 9.8 \text{m/s}^2 \) at the surface of the Earth is given by

\[
g = \frac{4\pi G}{3} \rho_{\text{Earth}} R_{\text{Earth}}.
\]

Dividing the last two equations, we find that

\[
g_{\text{below}} = g \frac{R_{\text{below}}}{R_{\text{Earth}}}
\]

All this implies that as the vehicle moves closer to the center of the Earth, the force of gravity on it weakens. At the crash site it is already 20\% less. This conclusion has some serious implications; the people could not walk and move normally (contrary to what we see in the movie). In any case, ignoring such implications, we will only look at the sinking of the body.

Using the volume \( V \) and density of the object \( \rho_{\text{object}} \), we can now write

\[
F_{\text{gravity}} = \frac{R_{\text{below}}}{R_{\text{Earth}}} g \rho_{\text{object}} V.
\]

Besides gravity, once an object is inside the lava, there is also the force of buoyancy from the lava. This is equal to the gravitational force felt by the displaced lava:

\[
F_b = g_{\text{below}} M_{\text{displaced}} = \frac{R_{\text{below}}}{R_{\text{Earth}}} g \rho_{\text{lava}} V_b,
\]

where \( V_b \) is the volume of the object that is submerged in the lava. The net force on the body is thus

\[
F_{\text{net}} = \frac{R_{\text{below}}}{R_{\text{Earth}}} g (\rho_{\text{lava}} V_b - \rho_{\text{object}} V).
\]

Notice that, depending on the sign of the quantity

\[
\rho_{\text{lava}} V_b - \rho_{\text{object}} V,
\]

an object can float or sink.

The human body is made mainly of water, thus its density will be almost equal to that of water, \( \rho_{\text{water}} = 1000 \text{kg/m}^3 \). The lava is mostly molten rock; surface rocks have an approximate density of 3300 \text{kg/m}^3. So \( \rho_{\text{lava}} = 3300 \text{kg/m}^3 \). Therefore, for the human body, once a third of it submerges in lava, the two forces become equal and the body stops sinking. Even more, sinking (in lava) will happen at a slower rate compared to the rate on the surface of the Earth since gravity is weaker at that depth.
2.5 Ignorance of Angular Momentum and More

In the movie *Superman* [12], Superman, being unable to stand the loss of his great love Lois Lane, decides to reverse the rotation of the Earth so he can reverse time. He thus flies very high—outside the Earth’s atmosphere—and starts revolving around Earth at a great speed. After doing so for some time, the Earth finally slows down and then starts rotating in the opposite direction. This forces time to run backwards bringing the clock before the death of Lois. Once he succeeds in ‘resurrecting’ Lois, he changes his direction of revolution eventually forcing Earth to return to its original direction and rate of rotation\(^{10}\).

![Image](image.png)

Figure 10: Superman rotates fast around Earth. Unfortunately the directions of the rotations are not seen in this picture. The movie correctly shows Earth rotating from left to right as we look at this picture, while superman revolves around it from right to left.

There are few scenes in all of movies ever produced that rewrite so many physics laws as this one does. First of all, why the director relates the direction of Earth’s rotation to the direction of time is a mystery. Why not the direction of the Earth’s revolution around the Sun? Or maybe, the Moon’s revolution around Earth. Time is a ‘mystical’ quantity in our universe that is very hard to be explained. Even more, one can make a distinction about several different kinds of time: fundamental time, thermodynamic time, etc. Current proposed theories of unification delve into this topic but the issue is far from being resolved. However, one thing is very well understood: just changing of direction of the motion of an object will not do anything to the flow of time.

Even if the reversal in the direction of Earth’s rotation would reverse the flow of time, why, after the original direction of rotation has been restored, the events will

\(^{10}\)Time: 2:18:34–2:20:13
not repeat themselves in the same sequence\textsuperscript{11}? To allow for a different outcome, we must assume that Superman’s action created a parallel universe that is identical to the universe he knew up to the point that Lois may or may not be killed. At that point, Superman’s actions send him in one of the universes in which Lois is not killed.

All the previous discussion is really science fiction. Let’s not pursue it, but instead discuss more down-to-earth flaws of the scene. As we clearly see in the movie, Superman flies outside Earth’s atmosphere before he starts his revolution. It is easy to understand how he got there: he got a push from the ground, then from the air by pushing them in the opposite direction (action-reaction law). But if he is eventually outside the atmosphere, how does he propel himself? He cannot get a push from anything. He could in principle expels mass...which should come from his own body! Unfortunately, he cannot afford doing it\textsuperscript{12}. So, despite his good intentions, what he set out to do cannot be done, not even by Superman.

Even so, let’s assume that the impossible (propelling himself in empty space) is possible. The law that the director is using (actually, is attempting to use) is angular momentum conservation. Superman and Earth initially have a combined net angular momentum. If one of them changes its angular momentum, then the other must change it accordingly such that the sum will remain unchanged. Superman speeds up, so the Earth must slow down. However, the director has an incorrect understanding of the law. The movie shows Superman revolving around Earth in a direction that is opposite compared to Earth’s revolution. This is exactly opposite scenario of what the director wants: this will increase Earth’s rate of rotation. It is easy to see why. Superman will accelerate due to a push from Earth. He, of course, applies an opposite push to Earth. But if he flies in a direction opposite to Earth’s rotation, his push is along Earth’s rotation and, therefore, will speed up Earth’s rotation.

Again, let’s ignore this ‘little’ detail and assume that Superman flew in the correct direction. How far away from Earth should he be? And what should his speed be? Earth is approximately a sphere of radius $R = 6370\, km$ and mass $M = 6 \times 10^{24}\, kg$. The moment of inertia of a sphere rotating about a diameter equals $I = (2/5)MR^2$. Therefore its angular momentum is $L_{\text{Earth}} = I\omega$ where $\omega$ is $2\pi$ radians per day or $\omega = 7 \times 10^{-5}\, rad/s$. Superman is initially rotating with Earth’s speed:

$$L_{\text{superman}} = I_{\text{superman}}\omega = mR^2\omega.$$ 

Since superman’s mass (that we assume for simplicity to be about 100$kg$) is negligibly small compared to Earth’s mass, $L_{\text{total}} \simeq L_{\text{Earth}}$. When Earth comes to rest, only Superman has angular momentum

$$L'_{\text{superman}} = mv d,$$

\textsuperscript{11}If the events repeat themselves \textit{identically}, then notice that Superman created a perpetual loop of events. This loop will be repeated for ever.

\textsuperscript{12}Compute how much of his mass Superman needs to use in order to match Earth’s angular momentum.
where \( v \) is his speed and \( d \) his distance from the center of the Earth. Conservation of angular momentum requires

\[
mvd = \frac{2}{5} MR^2 \omega ,
\]

or

\[
v d = 68 \times 10^{30} \frac{m^2}{s}.
\]

For any distance that is less than \( d_0 = 2.3 \times 10^{23} m \), the required speed is greater than the speed of light \( c = 300,000 km/s \). Keeping his speed below \( c \), implies that he will have to go far away...further than \( d_0 \). The universe is about 14 billion years old. During this time, light has traveled a distance \( 1.3 \times 10^{26} m \). Certainly bigger than what Superman needs. But does he have time to finish what he started? He would need to be moving at nearly the speed of light in a circle whose radius around Earth is equal to the distance to the edge of the visible universe when it was 1/1000 of its present size.

## 2.6 Impressive Special Effects Imply Impressive Lack of Science Literacy

In *X-Men: The Last Stand* [13], Magneto, the leader of the brotherhood of X-Men that resists humans performs the following feat. When his army is ready to attack the island of Alcatraz where the research institute for the curing of the X-disease is located, he uses his ability of manipulating magnetic fields to cut the Golden Gate Bridge loose and relocate it between San Francisco’s port and the island[13]. The relocation of the bridge gave to the director an opportunity for great special effects. However, even with the acceptance of Magneto’s special powers, it is an unrealistic scene given the physical laws in our universe.

![Figure 11: Left: The section of the Golden Gate Bridge that Magneto transferred. Right: The traffic on the bridge before Magneto’s attack.](image)

[13] Time: 1:13:15–1:16:23.
Extensive information about the Golden Gate Bridge can be found at its website \[14]. In particular, the mass of Bridge, not including anchorages and north and south approaches, but including suspended structure, towers, piers and fenders, bottom lateral system and orthotropic re-decking is 419,800 short tons or 380,800,000 kg. Also, the length of the suspension spans, including the main span and side spans, is 1,966 meters. Given the quick shot of traffic on the bridge, we can approximate that when Magneto cut the bridge, we have about 1 car every 4 meters of the bridge. This is equal to a total of 393 cars. Since an average car is about 1,000 kg the total mass of the cars is about 393,000 kg. We may add the mass of the drivers and passengers in the cars but we can easily see that the main mass comes from the construction of the bridge, not the load. So, let’s assume that the combined mass is of the order of 400,000,000 kg.

Using a map we can see that the bridge must be moved about 5400 meters. The movie implies that the whole affair happens within few minutes. If this means 5 minutes, then the speed should be $18 m/s$ or about $65 km/h$. For simplicity, we shall assume a speed of $10 m/s$.

All this would imply kinetic energy of

$$K = \frac{1}{2} m v^2 = 20,000,000,000 \text{ J},$$

for the transportation of the bridge. Assuming that the bridge is not lifted above the ground more than its original clearance, there is no energy expended for potential energy. However, in order to break the bridge free work has to be done; we ignore this since it is harder to compute and adds nothing to the final conclusion.

The energy for the relocation of the bridge is provided by Magneto through the magnetic fields he can create. Ultimately the creation of the magnetic fields originates in the cells of his body that obtain the energy from the food consumed by Magneto. One Calorie is 4,200 Joules. Therefore, the energy required for the transportation of the bridge is equivalent to 4,761,900 Calories. An average male needs about 2,500 Calories a day just to support the smooth functioning of his body. Just the task of the transportation of the bridge requires the prior consumption of food for 1900 males. Since Magneto has not eaten anything while he is performing the task, the energy should come at the expense of his body mass. One pound of fat is about 3,500 Calories. In other words, Magneto should lose at least 1350 pounds while he transported the bridge!

Of course, transporting the bridge is by no means Magneto’s only feat. We watch him performing a series of feats, one after the other. Therefore, the problem is way more serious than what our calculation shows.

In order to be fair, we must observe that our comments above are valid only when Magneto’s body produces energy through chemical reactions. If the energy produced is due to nuclear fusion—exactly the same way energy is produced by the Sun—then
the difficulty we encountered disappears. During nuclear fusion, a change of mass is observed. The mass that was lost was converted to energy in accordance to Einstein’s celebrated equation:

\[ E = \Delta m c^2. \]

The transportation of the bridge would require a loss of body mass of 0.000000225 kg. This is a very small amount of mass.

In any case, even if Magneto does not have to lose body mass, the way the situation is presented in the movie is still unrealistic. The average power of Magneto’s body is

\[ P = \frac{20,000,000,000 \text{ J}}{540 \text{ s}} = 37,037,037 \text{ Watts}. \]

In the same way that the Sun or a light bulb shines when it produces energy, Magneto should also shine. It is worthwhile to understand how bright (literally) he should be. The filament of a standard incandescent 60 W light bulb is made of tungsten and it is about 2 m long and about 0.25 mm. This would imply a surface area of 0.003 m². Then the intensity of the light bulb is

\[ I_{\text{bulb}} = \frac{60 \text{ W}}{0.003 \text{ m}^2} = 20,000 \frac{\text{W}}{\text{m}^2}. \]

The surface area of the human body is about 1.8 m²; let’s round it up to 2 m². Then Magnetos’s intensity is

\[ I_{\text{Magneto}} = 18,518,519 \frac{\text{W}}{\text{m}^2}. \]

Magneto’s body should be shining about 926 times stronger than a 60W light bulb!

The scene has additional problems not directly related to Magneto. A suspension bridge takes its rightful name from the fact that the load of the bridge is suspended by vertical steel wires hung by cables [14] which, in turn, are secured between two towers. The towers are anchored by additional cables at the ground. All tension of the bridge and its load eventually is transferred to the ground through this series of cables. Magneto, in his attempt to relocate the bridge, cut the suspension cables of the bridge as the movie so clearly presents. However, once this is done, there is nothing to support the bridge with its load and, therefore, it should now collapse [15].

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[14] One can work out easily that, for uniform load, the shape of these cables must be parabolic. This gives the suspension bridges their familiar look.

[15] Of course, Magneto can choose to create a magnetic field to support the bridge while it is transported and while in use in its new location. Of course this must be done in the expense of more energy from his body. Incidentally, notice that it is not clear why Magneto chooses to carry his army with the bridge as he can—more easily—hijack a ship and (magnetically or manually) drive it to the island.
Notice that when Magneto drops the bridge on Alcatraz, he flies above it. It is not clear how the audience should interpret this. Should we assume that he does so to avoid the impact which is hard enough to create serious damage? Or should we assume that he does so to show his superiority? Probably, the latter since the director seems not to understand what the effect from the drop may be on the objects sitting on the bridge. None of the cars on the bridge, nor anyone of Magneto’s army seem to have been affected the slightest by the fall. An interesting problem for the reader might be the estimation of the force acting on the objects as a result of the fall of the bridge.

2.7 Artistic Exaggerations that Lead to the Ridiculous

In The Chronicles of Riddick there is a planet called Crematoria. It takes its name from the harsh environment it offers. As a spaceship approaches Crematoria, a quick close-up of the ‘Course Plotted’ panel is shown. There we read the temperature differential on the two sides of the planet, $-295^\circ F$ and $+702^\circ F$, while a crew member states loud “700 degrees on the day side; 300 below on the night side”.

Riddick, after being imprisoned in an underground prison in Crematoria, succeeds in escaping with a group of other prisoners just before sunrise. The group then starts to run towards a spaceship (which fortunately happens to be in the right direction) away from the coming sunshine that brings the devastating daylight temperatures. The race is hard. As they climb a cliff, Riddick’s old friend Kyra falls behind and the morning heat traps her behind a rock. Unable to leave Kyra face her fate, Riddick tries his ultimate trick: he drops the water from a flask on himself, ties a rope on the top of the cliff, swings and...saves Kyra. After the rescue, we still see the vapors from the water (and his sweat supposedly).

The reader after watching the scene will certainly have realized that, scientifically, it is rubbish. First of all, why are the escaped prisoners only afraid of the incoming sunshine? Why aren’t they also afraid of the dark side? Isn’t the temperature in the dark side $-295^\circ F$? Well, as always, let’s give the director the benefit of the doubt. Let’s pretend that due to the incoming heat and the fact that the heroes are caught

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16Magneto’s flying actually creates another hole in the movie’s plot. If Magneto has the ability to levitate humans, why not to just fly his arm to the island? An additional comment may be in order here since the reader may be wondering if it is possible to levitate humans by the use of magnetic fields. Actually, it is. All objects, including plastic, wood, and biological tissue, have magnetic properties that can be used in similar ways. However, such objects demonstrate only a very weak magnetic behavior. Therefore, one needs a large applied field in order to levitate them. Levitation of small biological objects (live frog, grasshopper, hazelnut, etc.) was first achieved by a group of researchers in the Nijmegen High Field Magnet Laboratory in the Netherlands.

17From the close-up we do not know if the temperature is measured in degrees Celsius or Fahrenheit.

18Time: 0:53:39–0:53:56.

19Time: 1:29:47–1:32:27.
Figure 12: Left: Riddick drops a flask of water on himself before attempting the rescue of Kyra. Right: Vapors of water are seen around the body of Riddick after the rescue of Kyra.

exactly in the middle of dark-light, the temperature they experience is something that they can tolerate.

At the heart of the scene is the harshness of the environment on Crematoria. The director has tried hard to make the audience appreciate how harsh the conditions are. He shows that, as the daylight comes, the ‘temperature differential’ creates a heat wave that incinerates anything it finds in front of it. One of the escaped prisoners attempted to look at Kyra’s rescue and was incinerated by the wave in seconds. After all this effort to present an impossible situation, the director then shows to the audience that a flask of water is the solution... This is worth of some discussion.

Figure 13: A sequence of stills from the incineration of one the escapees. The incineration happens in seconds.

Actual cremation takes place at an initial temperature of 700°C (1290°F) which increases to 900° – 1100°C (1650° – 2010°F) during combustion. The cremation lasts 60-90 minutes for obese people and up to 120 minutes for thin and underweight people. The temperature on Crematoria is way below the required temperature for incineration. It simply cannot happen and if it could, the time shown for it is nonsense. In the piece *Special Effects Revealed* of the DVD bonus features, Peter Chiang, Visual Effects Supervisor, explains that the original script, written by David Twohy, was using degrees Celsius. It would be nice if a simple error would be a solution to this problem. With this point of view, the temperature is enough to start the cremation
but still below that required at the later stage. It would require, at least, the full time of cremation to get the ashes of the incinerated people. However, there is an even worse problem in this interpretation. The temperature $-300^\circ C$ does not exist! The lowest temperature in our universe is that of the absolute zero and this is $-273^\circ C$.

Although the temperature is not high enough to get spontaneous incinerations, it is too high for survival. Our heroes should be fried. At such intense temperatures, the moisture of the skin will evaporate quickly and the dry skin will be severely damaged. Let’s look at the water Riddick dropped on himself. From the size of the flask, we must assume that it was not more than 1 liter (equivalently 1 kilogram in mass)—in fact this amount is probably an exaggeration. Most of the water is lost; very little will adhere to his skin. We will use his head as example for the calculation. Probably no more than 10g of water will remain on his head. Say that the water was absorbed uniformly by the head. If we approximate the surface area of the head to be $0.2m^2$ then the water density covering Riddick’s head is $\sigma = 0.05kg/m^2$. We further assume that the water was at room temperature—say about $25^\circ C$. If $L = 2,257kJ/kg^\circ C$ is the latent heat of vaporization of water and $c = 4.2kJ/kg^\circ C$ is the specific heat of water, then the total energy per unit area $\epsilon$ required to evaporate the water is:

$$\epsilon = \sigma (c\Delta T + L),$$

or about $129kJ/m^2$. To find out how long it takes for this water to evaporate, we must approximate the intensity of the Sun’s energy output on Crematoria. We can get a rough estimation about this energy by looking at Mercury in our solar system. Mercury has a temperature differential similar to Crematoria, $-280^\circ F$ to $800^\circ F$. There are several notable differences however. Crematoria seems to have a rotation, a gravitational field, and an atmospheric pressure and content equal (or at least close) to those of Earth. This is not the case for Mercury. In principle, it is hard to understand how Crematoria could have maintained an atmosphere due to its proximity to the Sun. The solar wind should have washed the atmosphere out of the planet as it has been done on Mercury. However, the movie shows no worries about this, so we won’t worry about it either. The solar wind would have made a better special effect compared to the temperature differential used. In any case, we can hypothesize that, for some unknown reason, Crematoria has been able to maintain its atmosphere. Of course, having an atmosphere will create meteorological phenomena that will affect the temperature on the planet. All this indicates that the assumption that we can, as a rough estimate, equate the energy that reaches Crematoria to the energy that reaches Mercury. In any case, in astronomical units, Earth’s mean distance from the Sun is $d_{Earth} = 1AU$ and Mercury’s mean distance is $d_{Mercury} = 0.306AU$. Also, the intensity of sunlight on Earth, just outside the

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20It is actually an advantage that Riddick has shaved his head. Hair might retain a little more water but it will have way higher surface area leading to faster evaporation.
atmosphere, is \( I_{\text{Earth}} = 1.4\text{kW/m}^2 \). All this would imply a sunlight intensity at the surface of Mercury equal to

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I_{\text{Mercury}} = I_{\text{Earth}} \left( \frac{d_{\text{Earth}}}{d_{\text{Mercury}}} \right)^2 = 14.95\frac{\text{kW}}{\text{m}^2}.
\]

Therefore the sun delivers about 15\( \text{kJ/m}^2 \) per second and implies that the protective layer of water spread by Riddick would last less than 9 seconds under direct exposure to the sunlight. Of course, because the rising heat in the air, as soon as Riddick dropped the water on him, the water started to absorb heat. This reduces the time this protective layer needs for evaporation. Hopefully, he gains enough time from his sweat to finish his task otherwise his skin will get cooked...

### 3 Conclusions

Hollywood directors and special effects creators work hard to create impressive scenes in movies to excite the audience. However, many scenes are created with absolute disregard of the physical laws in our universe. Sometimes the scene is so profoundly wrong that it is hard to be missed. However, often the absurdity is hard to detect by people not very fluent in science literacy and untrained in critical thinking. In this way, Hollywood is reinforcing (or even creating) incorrect scientific attitudes that can have negative results for the society. This is a good reason to recommend that all citizens be taught critical thinking and be required to develop basic science and quantitative literacy.

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