During the past several years the authors have developed a new approach to the teaching of Physical Science, a general education course typically found in the curricula of nearly every college and university. This approach, called Physics in Films [1], uses scenes from popular movies to illustrate physical principles and has excited student interest and improved student performance. A similar approach at the high school level, nicknamed Hollywood Physics, has been developed by Chandler Dennis [2, 3]. The two approaches may be considered complementary as they target different student groups.

The analyses of many of the scenes in Physics in Films are a direct application of Fermi calculations — estimates and approximations designed to make solutions of complex and seemingly intractable problems understandable to the student non-specialist. The intent of this paper is to provide instructors with examples they can use to develop skill in recognizing Fermi problems and making Fermi calculations in their own courses.

1 Fermi, Socrates, and Orders of Magnitude

1.1 In the Beginning there was Fermi

In the early morning of July 16, 1945, the first atomic bomb exploded near Alamagordo, New Mexico. Watching at the main observation post a few miles from ground zero was Enrico Fermi (1901–1954), the Italian physicist who had built the first man-made atomic reactor a few years before. About 40 seconds after the bright detonation flash, as the air blast reached his location he dropped a handful of torn bits of paper from a height of about 1.5 meters above the ground. There being no wind that morning, he measured their displacement at the ground, about 2.5 meters, as the air blast passed him. Doing a quick, approximate calculation, he estimated the strength of that first atomic bomb explosion to be equivalent to about 10,000 tons of TNT [4]. His quick calculation missed the actual strength of the explosion, as measured by the instrumentation, by less than a factor of two!

Fermi had an extraordinary ability to answer with reasonable accuracy any question posed to him, questions that would seem impossible to answer to an ordinary
The classic example of such questions that is attributed to him is ‘How many piano tuners are there in the city of Chicago?’ Asking this question, even of trained scientist, will initially create frustration and a feeling that the answer may be unattainable, at least without referring to the piano tuners’ union website. However, upon second, more careful thought, one discovers that the question can be split into a series of simpler questions which admit approximate answers leading eventually to an approximate (but very reasonable) answer to the original question:

1. What is the population of the Chicago?
2. How many families does this correspond to?
3. What fraction of families have pianos?
4. What is average number of piano tunings per year per family?
5. What is the average number of piano tunings per year that a tuner can make?

‘Fermi problems’ thus have a very distinct profile: they always seem vague with very little or no information given, but they admit dissection into a set of simpler questions that lead to the final answer. Once understood, Fermi problems become a source of limitless fun. An answer found is a blast of excitement and joy.

1.2 Socrates’ Dialectic Method

Socrates (470–399 BC) was an Athenian philosopher and teacher of Plato. One of the most significant philosophers of the western world, he had (through Plato) direct influence on modern thought. Socrates established the Socratic method (dialectic
method). The method is probably used by many—in not all—of us. Basically, through a series a questions and answers the interviewer leads a person who thought he knew something to a realization that he does not. Alternately, the series of questions and answers is used to prepare the development of a more sophisticated structure. Isn’t this that we do all the time in the classroom? Looking carefully at the concepts, Fermi Problems are a variation of the Socratic method. The answer has to be extracted from the person who was asked the Fermi Problem. However, in order for him to answer the question, he has no other choice but asking himself a series of questions that will help him reach a solution. Indeed, the Socratic method is at the heart of the method of solving Fermi Problems.

1.3 Orders of Magnitude

Physicists have a lifelong addiction to comparing sizes. Words such as ‘small’ and ‘large’ are useless in physics in favor of more precise terms such as ‘small compared to’ and ‘large compared to’. The standard units—those of SI—are usually scaled appropriately to make smaller and larger sizes. For simplicity, prefixes that are multiples of 10 have been introduced to standardize the system. Table 1 lists the frequently used prefixes.

| PREFIX | SYMBOL | VALUE |
|--------|--------|-------|
| ...    | ...    | ...   |
| tera   | T      | $10^{12}$ |
| giga   | G      | $10^9$ |
| mega   | M      | $10^6$ |
| kilo   | k      | $10^3$ |
| hecto  | h      | $10^2$ |
| deka   | da     | 10    |
| deci   | d      | $10^{-1}$ |
| centi  | c      | $10^{-2}$ |
| milli  | m      | $10^{-3}$ |
| micro  | $\mu$ | $10^{-6}$ |
| nano   | n      | $10^{-9}$ |
| pico   | p      | $10^{-12}$ |
| ...    | ...    | ...   |

Table 1: Standard prefixes in SI.

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4Size here refers to the magnitude of any physical quantity; it is not restricted to the physical dimensions of an object.
By making use of the prefixes and standard units, physicists get a feeling for the magnitude of a quantity which is often rounded off to the nearest power of ten. For example, the average life of a human is of the order of $10^2$ years and the age of the universe is of the order of $10^{10}$ years. A nice visualization of 39 orders of magnitude can be found in the website [6], which is based on the classic film by Charles and Ray Eames [7]. A modern remake can be seen in the IMAX film *Cosmic Voyage* [8] that presents a narrated cosmic zoom across 42 orders of magnitude.

Real-life problems encountered by physicists are almost always hard and few admit analytical solution. Physicists, in an effort to understand the scales involved, approach them as Fermi Problems. Once a rough estimation is obtained and the range of the answer is known, educated decisions can be made as to which approaches and techniques are optimum for a more precise, but probably still approximate, solution.

An interesting example of a Fermi Problem that captures students’ attention in general education physical science and astronomy courses is the question ‘How many technologically advanced civilizations exist in our galaxy?’ The question was first asked and answered by astronomer Frank Drake; consequently, the equation that estimates that number is known universally as *Drake’s equation*. To answer Drake’s question we need to approximate

1. the number of stars in our galaxy;
2. the fraction of stars that admit solar systems;
3. the average number of planets in these solar systems that are in the habitable zone;
4. the fraction of the planets that will develop life;
5. the fraction of the planets in which life will involve intelligent life;
6. the fraction of the plants in which intelligent life will advance to create technological societies;
7. the lifetime of such civilizations.

### 2 Why Fermi Problems in General Ed?

According to surveys by the National Science Foundation [9], while 70 percent of the U.S. population know that Earth moves around the sun, only half know that it takes one year to do so. Over half think that early humans lived at the same time as the dinosaurs. Only about 42 percent know that electrons are smaller than atoms and barely 35 percent know that the universe started with a huge explosion. Clearly, the
traditional science general education courses, particularly physical science, are not doing their job of fostering science literacy.

In the summer of 2002 the authors began the Physics in Films version of the physical science course with goal of improving the science literacy of the thousands of non-science students who take the course at our institution each year. In the process of the continuing development of that program it has been discovered that general education students, who normally shudder at the thought of doing calculations of any kind, readily accept and learn to emulate the Fermi calculation approach to dealing with seemingly very difficult, if not impossible problems. Here is a quick and simple example that can help demonstrate the method even at the first meeting of the class and at the same time use content related to the class.

2.1 Speed ... of Earth!

The concept of ‘speed’ is one that arises early in physical science. Many students know that a world-class runner can sprint 100m in 10s (or less), but have no clue about how fast, i.e., at what speed the runner is moving. Similarly, they know that a hot sports car will accelerate to 60mi/h (97km/h) in 3.5s, but don’t how to find the average speed of the car. We find that by introducing them to the Fermi calculation approach to determining a speed they initially see as impossible for them to find, they gain confidence. They discover that (a) they can solve the simple problems like those above and (b) they retain more, having ‘done it themselves’.

To find the speed of Earth, some numbers are needed, many of which students generally may not know. Table 2 contains some useful data for Earth. Earth’s speed is given by:

\[ V_{Earth} = \frac{\text{distance traveled}}{\text{time required}}. \]  

In one year Earth completes one orbit around the sun, so the distance traveled is the circumference \( C \) of the orbit and the time required is one year.

\[ C = 2\pi R = 2\pi \times 150 \cdot 10^6 \text{km} = 9.42 \cdot 10^8 \text{km}, \]

where the radius \( R \) of Earth’s orbit is given in Table 2.

Converting one year into hours provides another opportunity to reinforce the treatment of units like numbers in multiplication and division.

\[ 1y = 1y \times \frac{365d}{1y} \times \frac{24h}{1d} = 8,760h. \]  

\[ ^5 \text{George Goth has tabulated a long list of data} \text{[10]} \text{that are useful in answering a very wide range of Fermi problems.} \]
Table 2: Some data for Earth for Fermi calculations.

| Physical Quantity                                | Magnitude         | Units |
|-------------------------------------------------|-------------------|-------|
| Area of Earth’s oceans (% of total)              | 70.8              | %     |
| Mass of Earth                                    | 5.97 · 10^{24}    | kg    |
| Radius of Earth                                  | 6.37 · 10^{6}     | m     |
| Thickness of Earth’s outer core                  | 2.27 · 10^{6}     | m     |
| Radius of Earth’s inner core                     | 1.2 · 10^{6}      | m     |
| Radius of Earth’s orbit around sun               | 1.5 · 10^{11}     | m     |

Now we can find Earth’s speed from equation (1):

\[ V_{Earth} = \frac{9.42 \cdot 10^8 \text{ km}}{8,760 \text{ h}} = 108,000 \text{ km/h} . \]

and the students are amazed! During the hour they spent in class they have traveled through space a distance of more than 2.5 times Earth’s circumference at the equator!

Strictly speaking, the speed of Earth around the Sun, as presented above, is a straightforward calculation, not a Fermi problem since we copied the Earth radius about the Sun—which is the central quantity for the calculation—from an astronomical table. However, the question becomes a Fermi problem if we require that the Earth radius about the Sun cannot be read from any table but, instead, should be derived from simple known facts. To this end, one may, for example, use the well known fact that light from Sun reaches Earth after 8 minutes. Therefore the distance between Earth-Sun is 8-light minutes or about 144,000,000 kilometers. Of course, using the travel time of light between Sun and Earth is not the only piece of information that can be employed. Which data are considered known in a Fermi Problem is arbitrary; the solver is free to utilize all his knowledge and his ingenuity.

3 Cinema Fermi Problems

Since our goal is to train students in critical thinking and reasoning, the Fermi Problems discussed in class are more sophisticated than those in the previous section. Almost all of them rely on information presented in a movie. We call such problems Cinema Fermi Problems. The students have to extract data from the spoken dialogue and the visual pictures. Often the calculation is quite intricate, similar to those encountered in a regular, algebra-based introductory physics course. An example of such a calculation is given in [1]. In that article the authors discussed the NASA plan in the movie Armageddon [12] to use the explosion of a nuclear bomb to split into two pieces an asteroid which is on a collision course with Earth. The two halves will be deflected away from Earth by the explosion. Based on the information given
in the movie and some additional reasonable estimates, it was shown that the plan would only result in Earth colliding with—instead one asteroid—two smaller fragments, each about half the size of the original asteroid hitting Earth just a few blocks apart. The authors skip calculations that could also be performed (such as three body calculations for the system moon-Earth-asteroid and the tidal forces on Earth from the asteroid) or discussions of an alternate real NASA scenario that has been proposed for such a situation [20]. Another Cinema Fermi Problem, based on the movie Speed 2 has been described by the authors in [11]. There the authors explain that the deceleration of the cruise ship that is crashing into the port is too small to have the catastrophic effects on the passengers of the ship, contrary to what is shown in the movie. Tretter [13] presents a Cinema Fermi Problem that deals with scaling. Scaling arguments are simple and powerful and known since Galileo’s time [14]. Below we present three additional Cinema Fermi Problems to help the reader become familiar with the concept. For our course, we have screened hundreds of movies and worked tens of such problems.

3.1 Gravity on a space station

Let’s do a bit harder Fermi problem, ‘What is the artificial gravity generated on a rotating space station?’ One example that the authors use in Physics in Films is taken from the movie 2001: A Space Odyssey [15]. In the movie passengers on board the space station live normally. In scenes both inside of and outside of the station, they walk about, prepare food, sit in chairs, and there are no objects floating about as students are accustomed to seeing in television coverage of NASA’s orbiting space shuttles and the International Space Station or the old Mir space station. To answer the question we need to know (a) the rotational speed of the space station and (b) the radius of the station. The film provides us scenes showing people (who we assume are of average height), windows (whose size we estimate by comparison with the people), and external views of the slowly rotating space station (whose rotation period we can measure with a wristwatch) that show the same windows that were seen from inside. The size of the windows provides a way to estimate the radius of the wheel-shaped space station.
The film shows the rotation of the space station in real time. This enables the computation of the time needed for one full revolution. Figure 2 can be used in the estimation of sizes. The left picture can be used to relate the radius of the space station to the length of the windows. The second can be used to compare the length of the window to an average person. From the comparison of the lengths as explained above, we estimate that the radius $r$ of the space station is about 300 meters.

From the movie, we see that one-fourth of a rotation occurs in 9 seconds. Therefore, a full rotation of $2\pi$ radians occurs in 36 seconds. This corresponds to an angular speed $\omega$ given by

$$\omega = \frac{2\pi \text{ rad}}{36\text{s}} = 0.174 \frac{\text{rad}}{\text{s}}.$$ 

Then, the centrifugal acceleration that is felt as gravity on the outer ‘rim’ of the space station (where the people inside walk, their heads toward the station’s ‘hub’) is equal to

$$a_{\text{centrifugal}} = \omega^2 r = (0.174)^2 \times 300 \frac{m}{s^2} = 9.08 \frac{m}{s^2},$$

which is very close to $9.80m/s^2$, the acceleration of gravity on Earth.

Leaving this discussion, we present to our reader a related Cinema Fermi Problem. The inside view of the space station (see Figure 2) clearly shows a curving floor. Is the curvature of the floor consistent with the size of space station as shown in the outside view?

### 3.2 When a victory is worse than defeat

*Independence Day* [16] became a Hollywood blockbuster on the strength of its action and special effects. However, from the physics point of view this is one movie that hardly makes sense. In an effort to present the superiority of the aliens, the director attributes to them spaceships of impressive dimensions (both for the mothership and the battleships). These dimensions are simply huge and the approach of such a ship to Earth would have serious effects that are not, of course, presented in the movie. We shall not try to explore all problems raised by the basic plot of the movie; instead, we will only demonstrate that, under the premises of the director, humans will be obliterated. That is, we shall present a simple calculation to show that, even if humans successfully destroyed all of the battleships deployed above the major cities on Earth, the ultimate result would be holocaust for the human race. Casting this as a Fermi Problem, ‘What is the effect of destroying the alien space ship hovering over a major city?’ We need to know (a) how big is the ship; (b) what is its density; (c) what is its mass; and (d) what is its potential energy.

According to the movie, the battleships have a base diameter of 15 miles. This would imply a radius of 12 kilometers and a base area $A = \pi R^2$ of about $452.4$ square kilometers or $A = 4.5 \cdot 10^8 m^2$ in SI units. To place this number in prospective, the
borough of Manhattan in New York City is about 59.5 square kilometers. Just one battleship would cover about 8 Manhattans!

Figure 3: A spaceship hovering above a city in *Independence Day*. Ships of this size were deployed above every major city of the globe.

Watching the scene of the battle between the allied forces and the ship, we can get a feeling of its height and also at the hovering height above the city. Based on the stated diameter, we approximate the height $h$ of the ship to be 1 kilometer and its hovering height $H$ about 2 kilometers.

| Physical Quantity   | Magnitude | Units |
|---------------------|-----------|-------|
| Density of water    | $10^4$    | $kg/m^3$ |
| Density of Earth    | $5.52 \cdot 10^3$ | $kg/m^3$ |
| Density of aluminum | $2.7 \cdot 10^4$ | $kg/m^3$ |
| Density of iron     | $7.87 \cdot 10^3$ | $kg/m^3$ |
| Density of copper   | $8.96 \cdot 10^3$ | $kg/m^3$ |
| Density of lead     | $11.4 \cdot 10^4$ | $kg/m^3$ |

Table 3: Some density data for Fermi calculations.

From Figure 3, we see that the battleship has the shape of a cylinder. Therefore, its volume would be $V = A \times h$ or $V = 4.5 \cdot 10^{11} m^3$. However not all of the volume of a spaceship is material; a lot of it should be just empty space. In order to estimate the mass of the ship, we must estimate how much of the volume is material. A rough estimate would be about 10 percent. Therefore $V_{\text{material}} = 4.5 \cdot 10^{10} m^3$. But to estimate the mass of the ship, we also need to estimate the density of the material. Based on our current experience, spaceships are made of alloys. The density of metals is quite high (See Table 3). However, let us assume that we are dealing with an extremely advanced species, far more advanced than humans. It has mastered interstellar travel after all. So, it seems reasonable, that the species has discovered a new material of high strength but low density—close to the density of water, $\rho = 1000 kg/m^3$. Therefore, the mass of the ship would be $m = \rho V_{\text{material}} = 4.5 \cdot 10^{13} kg$. 
Hovering at a height of 2 kilometers, the ship has stored \(E = mgH = 88.2 \cdot 10^{16} J\) of potential energy. This energy will be released as heat after the allied forces destroy the ship and it falls on the ground. Recalling that the Hiroshima bomb released an amount of \(5 \cdot 10^{13} J\) of energy, the fall of the ship corresponds to the detonation of 17,640 Hiroshima bombs! Remember, this happens above every major city on Earth!

3.3 Scientists who never studied Physical Science

Probably, the worst movie that Hollywood has ever produced is *The Core* [17]. The director worked hard to rewrite the majority of the basic laws of physics. Eventually, he succeeded. Like *Armageddon* and *Independence Day*, this movie can be the topic for numerous topics in physics. Here, we shall concentrate only on the Army’s plan to undo the problem that it created: a secret project funded by the Army is responsible for slowing the rotation of Earth’s outer core. To better understand this statement and its implications, a brief explanation is in order.

![Figure 4: The onion-like structure of Earth. Picture is borrowed from [19].](image)

Figure 4 shows a cross section of Earth. Earth has an onion-like structure. It is made of several shells: the crust, the mantle, the outer core, and the inner core. We live on the surface of the crust. But the other shells are as important as the crust. The outer core is made of molten iron and rotates relatively fast: it completes one full revolution in one day. This gives the outer core an angular speed of

\[
\omega_{\text{outer}} = \frac{2\pi \text{ rad}}{1 \text{ d}} = 7 \cdot 10^{-5} \text{ rad/s}.
\]

The inner core is solid and rotates very slowly: only 1.5 degrees a year. (This is equivalent to an angular speed of \(\omega_{\text{inner}} \sim 10^{-9} \text{rad/s}\).) Electric charges (ions and...
electrons) circulating with the rotation of the iron in the outer core are the likely source of Earth’s magnetic field. This field, in turn, protects us from harmful cosmic radiation (mostly protons from the sun). In the movie, since the outer core has slowed considerably and it is about to stop rotating, the effects of cosmic rays on Earth start to be evident. Although we could explore other obvious questions, such as, ‘How did the Army manage to stop the core’s rotation so effectively?’; ‘What happened to the stored energy?’; and ‘What else would happen to Earth if the rotation of the outer core stops?’, we shall only deal with the plan to restore the rotation of the outer core. The scientists have concluded that the only way to restore the rotation of the outer core, is to carry a bomb of 1,000 megatons to the outer core and explode it. Leaving aside the question ‘How easy is it to get there?’, we will estimate how much rotation could be restored with the bomb they used.

The Hiroshima bomb was 12 kilotons and released $5 \cdot 10^{13} J$ of energy. Therefore, the bomb carried to the outer core will release approximately $E = 4.2 \cdot 10^{18} J$. Assuming that all this amount will become rotational energy of the outer core (of course, not true), the angular speed given by the the explosion is found by the equation:

$$E = \frac{1}{2} I_{outer} \omega^2,$$

where $I_{outer}$ is the moment of inertia of the outer core. This can be computed very easily since inertia is an additive quantity and the outer core is a spherical shell: If $R_o, R_i$ are the radii of the surfaces of the outer and inner cores respectively and $I_o, I_i, M_o, M_i$ stand for the moments of inertia and masses for the spheres with radii

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6 The movie shows to us that the bomb is placed inside the outer core. As such, all forces that develop are internal and one could argue that no rotation could be created as a result of the explosion. However, the director is lucky here. Internal forces, although they give a zero net result, they can create a non-zero torque. For example, let’s look at the two-body system of the following figure.

![Diagram](attachment:two_body_system.png)

 Obviously, the net torque is

$$\vec{\tau}_{net} = \vec{r}_1 \times \vec{F} - \vec{r}_2 \times \vec{F} = (\vec{r}_1 - \vec{r}_2) \times \vec{F}.$$  

The net torque will vanish only if the interaction between the two particles of the system is along the line that joins the particles. This is true for most cases but not necessarily all situations. We will thus give the director the benefit of doubt and assume that releasing the bomb inside the outer core is fine.
\( R_0, R_i \) respectively, then

\[
I_{outer} = I_o - I_i = \frac{2}{5} M_o R_o^2 - \frac{2}{5} M_i R_i^2 .
\]

If \( \rho \) stands for the density of the outer core, then \( M_o = \rho (4\pi/3) R_o^3 \), \( M_i = \rho (4\pi/3) R_i^3 \), and

\[
I_{outer} = \frac{8\pi}{15} \rho (R_o^5 - R_i^5) .
\]

It is known that \( R_o = 3470km \) and \( R_i = 1220km \) and \( \rho = 7870kg/m^3 \) (see tables \(2\) and \(3\)). Substituting all numbers in the equations we find

\[
\omega \simeq 10^{-9} \text{rad/s} .
\]

But this is 70,000 times smaller than the original angular speed! So, using a bomb that is equivalent to 83,000 Hiroshima bombs is not going to make any difference. They should have carried a bomb that was equivalent to 406,700,000,000,000 Hiroshima bombs. Recall that this assumes that all energy given off by the explosion will become rotational energy. And, ... as always, the scientists who did the calculations were the best humanity has ever produced! A Fermi Problem calculation revealed the absurdity of this plan.

### 3.4 What seems obvious is not always right

We are familiar with human motion on Earth. We are also familiar with human motion on the Moon. From the many pictures NASA has popularized, almost everyone knows that the Moon has low gravity and walking is hard there. Instead, leaping is quite effective.

![Figure 5](image)

Figure 5: A team of people walks on the surface of Mars as it would walk on Earth. Still is taken from *Red Planet* [18].
Hollywood has also popularized a planet Mars where everything happens as usual. Recently, astronomers have been talking about Mars and drawing attention to the fact that Mars is similar to Earth. In fact, in the distant past Mars was very much like Earth with oceans of water and the possibility of harboring life. Hollywood has taken the opportunity and has produced a number of movies where life on Mars looks identical to Earth. (By this, we really mean the mechanics and response of the human body to Martian gravity.) As a Cinema Fermi Problem, we would like to determine how close to reality Hollywood’s depiction of Martian living has been.

| Physical Quantity | Magnitude | Units |
|-------------------|-----------|-------|
| Mass of Moon      | 7.35 · 10^{22} | kg    |
| Radius of Moon    | 1,740     | km    |
| Mass of Mars      | 6.42 · 10^{23} | kg    |
| Radius of Mars    | 3,400     | km    |

Table 4: Some data for Fermi calculations.

The acceleration of gravity on a planet (or satellite) is given by the simple formula

\[ g = G \frac{M}{R^2}, \]

where \( G \) is Newton’s universal constant of gravity, \( M \) and \( R \) are the mass and radius of the planet (or satellite), respectively. We can apply the same formula for Earth

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

where \( g_{Earth} \) is the well known 9.80\( m/s^2 \). Dividing the previous two formulæ, and solving for \( g \), we find:

\[ g = g_{Earth} \frac{M}{M_{Earth}} \left( \frac{R_{Earth}}{R} \right)^2. \]

Using tables 2 and 4 we find

\[ g_{Moon} = 0.17 g_{Earth} = 1.67 \frac{m}{s^2}, \]
\[ g_{Mars} = 0.38 g_{Earth} = 3.72 \frac{m}{s^2}. \]

The acceleration of gravity on Mars is about twice that on the Moon, but still only 40 percent of that on Earth. Locomotion on Mars cannot be identical to that on Earth. Here is a quick way to understand this. Let \( V \) be the speed of walking of a human
in a gravitational field $g$ and $L$ is the length of his leg. Treating the leg as a solid rod that rotates about its one end, the (centripetal) acceleration at the other end is $V^2/L$. However, this acceleration can be at most $g$ (since the motion happens under the influence of gravity only). Then

$$\frac{V^2}{L} \leq g \Rightarrow V \leq \sqrt{gL}.$$ 

The length of the leg of a human adult is of the order of 1m. Therefore, the maximum walking speed is

$$V_{\text{max}} = 3.13 \frac{m}{s}, \quad \text{on Earth},$$

$$V_{\text{max}} = 1.93 \frac{m}{s}, \quad \text{on Mars},$$

$$V_{\text{max}} = 0.62 \frac{m}{s}, \quad \text{on Moon}.$$ 

## 4 Concluding Comments

There is a growing concern among scientists of the effect the entertainment industry has on the public [21]. Since not everyone who watches movies and TV series perceives the presented material as fictional and an artistic creation for entertainment only, the unchallenged presentation of pseudoscientific and scientifically inaccurate topics by this industry creates and reinforces unfounded beliefs that threaten the scientific literacy of the society.

Even worse than the spread of pseudo and incorrect science is the negative stereotype of scientists that the entertainment industry has created [22, 23, 24] and how willing it is to defame them in the name of quick profit. In the words of Evans [22]:

> Popular entertainment media have long portrayed scientists as mad, bad, and dangerous to know, but in the past few decades entertainment media portrayals of science have changed significantly, and these changes seem to have accelerated in recent years. Science remains dangerous, but it is also increasingly portrayed as useless in solving problems. The skepticism about paranormal claims that is a part of scientific thinking is portrayed as a handicap. And in many newer entertainment media offerings the paranormal is portrayed as, well, normal ... 

Film and television entertainment programming increasingly portrays science and reason as tools that are unsuitable for understanding our world in a new age of credulity ... 

... Our entertainment mass media provide a steady diet of negative images of science and skepticism—images that reflect and reinforce popular misgivings and misunderstandings about science.
Given such a harsh antiscientific environment, it seems natural for the public to develop a strong negative impression of science and many young people to consider it an undesirable career. Our course Physics in Films is an effort to start challenging the material presented to the public by the entertainment industry and eventually reverse the observed trend of declining scientific literacy. The use of Fermi problems and calculations in the way demonstrated in this article has proven to be a significant factor in students’ improved understanding of the principles of physical science [1, 25]. Even though at the beginning they could not individually perform the analyses nor, for most of them, the algebra involved, they quickly learn to follow the mathematical arguments and begin to think critically regarding other scenes in the movies. Our hope and expectation is that they will extend this new-found ability beyond the classroom.

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