Using Science Fiction Movies in Introductory Physics

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This paper discusses the use of science fiction movies in introductory physics courses at Spelman College. There are several reasons to use these movies in the classroom environment. Movies are a *visual* learning aid. Introductory physics students show a strong interest in participating in movie-related activities compared to standard group problem-solving sessions. Finally, these activities encourage creative thinking and can be used to develop writing skills. The students involved with these movie-based activities have included biology and pre-medical majors taking general physics. In the introductory level courses, physics, chemistry, and engineering majors worked on movie-based activities.

Motivation

Certainly, most physics teachers are aware that 21st-century students have much experience with processing visual information. Today's students have routinely played computer games and watched television as children. Other instructors have taken advantage of this knowledge and incorporated movie-based activities into high school physics classes.[1,2]

Along with other instructors, I believe there are benefits for using movie-based activities in undergraduate physics courses.[3] In addition to taking advantage of the students' visual learning skills, we take advantage of their strong interest in movies. In our general physics class (required for pre-medical majors) physics is not the primary interest of these students. However, they are interested in science fiction movies, since they are already familiar with the movies as part of the popular culture.[1,2] Physics III: Optics and Modern Physics, the third course in the introductory sequence, is designated as the writing-intensive course for the physics major. In this course, an essay assignment discussing the physics presented in a science fiction movie has been used successfully to develop writing skills.

Activities Using Films

I have used three types of assignments involving sci-fi movies. One assignment, mentioned above, is to have students choose a film and write an essay discussing the physics presented in it. Some movies chosen by the Physics III students were "Contact,"[4] "Deep Impact,"[5] and "The Matrix."[6] The filmmakers of "Contact" and "Deep Impact" strived to be accurate in their depictions, while "The Matrix" contained much "bad physics." Students recognized and discussed concepts that had previously been presented in class. As an example, a student writing about "Contact" discussed wave superposition (a Physics III topic) and the Fourier analysis of a radio signal coming from Vega.

These essays also helped point out misconceptions that students held, which was an unexpected benefit of the assignment. These misconceptions included misunderstanding class material; a student used the term "reference frame" to refer to a character's opinion about events happening in the film. This essay gave the instructor an unexpected opportunity to reinforce the physics definition of reference frame over the popular definition. Other students revealed faults in astronomy knowledge by writing "if a planet were destroyed a black hole would be created," and "an

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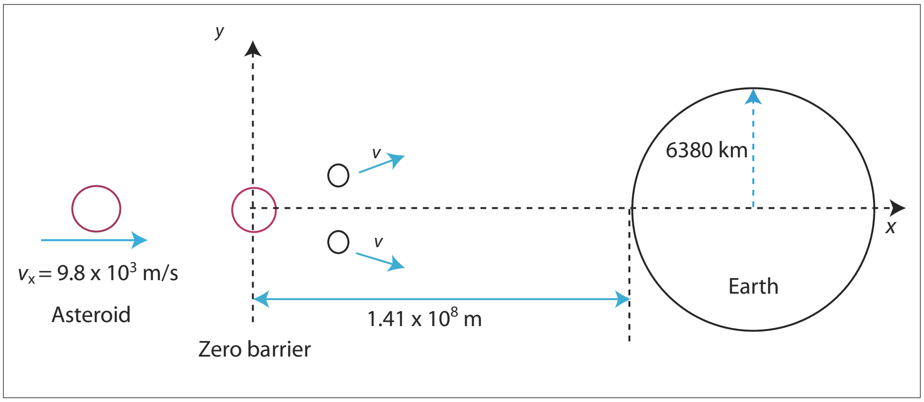

Fig. 1. Asteroid approaching Earth in the movie "Armageddon" breaks into two pieces at "zero barrier." The center of mass travels along the *x*-axis, while the two pieces each have velocity *v*, with velocity components $v_x = 9.8 \times 10^3$ m/s and $v_y = 1 \times 10^{-3}$ m/s.

asteroid is formed from dying stars." Because astronomy is not a course offering at Spelman College, such an error would have normally gone unnoticed during the student's college career. Therefore, the essay assignment proved to be valuable.

In addition, two other types of assignments follow in-class showings of brief film excerpts. Students either 1) discuss examples of correct and incorrect physics as presented in the scene, or 2) make calculations using the film's "data" to determine whether or not the physical quantity involved is reasonable. An example of the second activity was developed from the movie "Armageddon"[7] for the Physics I: Mechanics recitation.

"Armageddon" Activity

For this 50-minute, group-work assignment, students are first given a brief background on the movie's plot:

> In the movie "Armageddon," NASA realizes Earth has 18 days before it is destroyed by impact with an asteroid the size of Texas. Their solution is to land a team of oil drillers and astronauts on the asteroid, drop a nuclear warhead into its core, and split the asteroid into two pieces that will safely pass by the Earth. This must happen before "zero barrier," four hours before impact.

The class then watches two brief scenes from the film totaling approximately six minutes.[7] It is then up to the students to determine if NASA's scheme will really work. The asteroid is said to be the "size of Texas," and the class is told that Texas is approximately 900 miles (1.45×10^6 m) across. Students are given an approximate value for density of rock, $\rho \approx 3000$ kg/m^3; therefore, they can calculate the mass of the asteroid by approximating its geometry to be spherical.

Our class uses a textbook in which momentum is presented before energy.[8] Students have not yet been introduced to energy when this activity is given; therefore, they are told to assume that all of the energy from the explosion is converted to kinetic energy. The class is also told how kinetic energy relates to the speed (the *y*-component of velocity *v* in Fig. 1) with which the asteroid halves move apart:

$$v_y = \sqrt{2K/m}. \tag{1}$$

The total energy ($\approx 4 \times 10^{15}$ J for a typical one-megaton nuclear warhead) is divided equally between the two halves of the asteroid; thus, each half receives a kinetic energy of $K = 2 \times 10^{15}$ J. The mass of each half of the asteroid is $m = 2.4 \times 10^{21}$ kg, one-half of the total mass. Given this information and Eq. (1), students estimate the speed to be $v_y \approx 1 \times 10^{-3}$ m/s.

The students must make several assumptions to determine if the asteroid will pass Earth safely. The first assumption is that the gravitational effects of Earth can be neglected. Second, all energy from the explosion goes into kinetic energy of the asteroid halves; consequently, students must realize that they are greatly overestimating the effects of the explosion. Finally, the asteroid-nuclear weapon system is an essentially isolated one. Given these assumptions, the students deduce that momentum of the asteroid is conserved, and that the asteroid's center of mass passes through the Earth (Fig. 1). From this point, the students simply use their knowledge of kinematics to calculate how far the two halves travel in the *y*-direction, and then they compare this distance with the Earth's radius, which is the minimum distance needed to spare Earth.

Since this scenario must occur before the asteroid reaches "zero barrier," the students realize they have a minimum time of four hours (1.44×10^4 s) before the asteroid's center of mass reaches Earth. Therefore, the two halves each deflect by a total distance

$$\Delta y = v_y \cdot \Delta t \approx \left(10^{-3}\,\mathrm{m/s}\right)\cdot\left(1.44\times 10^{4}\,\mathrm{s}\right) \approx 14\ \mathrm{m}, \quad (2)$$

which is a distance well below the minimum distance needed, 6.38×10^6 m.

Conclusions

The students are generally shocked when they realize that the plan in "Armageddon" is not going to work. However, they are also very excited upon recognizing such a crucial error in the plot of a movie that they originally accepted without question. The use of movies in an introductory physics class is beneficial for many reasons. Primarily, the visual nature of movies transmits an idea to students quickly and clearly. Essays written about the physics presented in science fiction movies allow the instructor another way to address student misconceptions. Finally, because students are already interested in popular movies, they will most likely be more involved in the movie assignment than in a typical problem-solving assignment.

Acknowledgments

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Magnetic Therapy: Have We Got News for You! It Doesn't Work

"A study in the journal of the American Medical Association, 'Effect of Magnetic vs. Sham-Magnetic Insoles on Plantar Heel Pain,' reports that a randomized, double-blind, placebo controlled trial of 101 adults diagnosed with plantar heel pain found no significant difference in outcome between use of active vs. sham magnets. It was carried out by capable physicians from the prestigious Mayo Clinic. They even got the right answer. So what's the problem? The problem is the huge cost to society of disproving claims for which there was no evidence to begin with."[1]

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