Physics in Films

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Introduction

Have you ever been in the dark theater watching some phenomenal stunt in an action movie and ask yourself, "Could that really happen?" Have you ever wondered if it is possible for a bus to jump a 50 foot chasm and continue to drive at 50 mph? Could you survive an elevator free-fall of five stories? How bullets can throw some targets violently across rooms while others fall forward? Using the physics principles studied in my honors physics class, my students will dissect these and other unbelievable movie stunts to determine if they can possibly occur. The students will apply their knowledge of projectile motion, circular motion; use the principles of conservation of momentum and circuit analysis to determine if what they see in action-adventure movies is truly possible. As a class we will dissect scenes from several movies together and apply our knowledge of physics to prove whether the physical action is truly possible. Then my students will find their own action-adventure scenes and determine if they are physically possible or just movie magic and present their results to the class.

Classroom Environment

I teach at an urban high school with a population that is about 46% African American, 39% White, 11% Hispanic and 4% other. I teach introductory algebra-based physics to tenth, eleventh and twelfth grade students on a semester block program. I have the students for ninety minutes every day for one semester. The tenth grade students are part of the International Baccalaureate (IB) magnet program at my school. I teach between thirty and fifty tenth grade IB students who are self-selected for this program and they take introductory chemistry in the same year, therefore some students have completed chemistry but not all. The upper classmen have all completed chemistry and are divided between honors and regular level which they choose. The curriculum unit is developed for the introductory physics course. I also teach advanced placement (AP) algebra and calculus based physics courses and will use most of the curriculum unit materials in the algebra based AP physics class.

Rationale

From Bertolt Brecht's Galileo:

> Galileo: I believe in the human race. The only people that can't be reasoned with are the dead. Human beings are intelligent.
>
> Sagredo: Intelligent---or merely shrewd?
>
> Galileo: I know they call a donkey a horse when they want to sell it, and a horse a donkey when they want to buy it. But is that the whole story? Aren't they susceptible to truth as well? If anybody were to drop a stone and tell them that it didn't fall, do you think they would keep quiet? The evidence of your own eyes is a very seductive thing. Sooner or later everybody must succumb to it.[1]

The evidence of our own eyes is certainly strong; what happens if using the magic of movie making we change the truth? Overtime will the "seductive" nature of our eyes make us believe that it is possible for humans to jump from a bridge and catch a hovering helicopter? In my curriculum unit I want my students to deconstruct scenes from action-adventures movies and using their knowledge of physics principles prove that what they are seeing with their own eyes is either possible or not. Students will work as a team to find the accuracy of their own movie's physics and present the results to the class. I will limit students to action-adventure movies because these movies are expected to display what actually is possible in nature. Where science fiction or fantasy movies by their nature are based on writers imagination and do not have to strictly adhere to the laws of nature.

This curriculum unit can be used in two different methods, as a review of major objectives in physics at the end of the course before the final exam or as part of each topic within the individual units. For each topic that I address in a film my students will watch the scene and together as a whole class we will glean any physical information from the video such as speed, distance or time. Reasonable assumption will be made for any missing information necessary to solve the problem portrayed in the film. Modeling will be used to work through the problems describe in this curriculum unit. Addition problems will be assigned and worked either on white board or as homework. The North Carolina physics objectives that are addressed in this curriculum unit are described in appendix 3.[2]

Physics in Phyilms

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In my physics class, as in most, we begin with the study of motion or kinematics I am going to use several different scenes from the movie *Speed* to analyze the physics of motion. *Speed*, released in 1994, involves a crazed ex-police demolitions expert played by Dennis Hopper out to get revenge on his old colleagues, and extort a few million dollars out of the municipal budget by terrorizing the city with hidden bombs. It is up to

Keanu Reeves, a police officer, and city bus passenger turned bus driver Sandra Bullock to save the day.[3]

Projectile motion

The first scene we will analyze is scene 15 the famous bus jump. A bomb was placed on a city bus and is armed the first time the bus went over 50 mph and it will now detonate is the bus goes under 50 mph. The bosses at the police department direct the bus to an uncongested route containing an unfinished overpass bridge with a 50-foot gap. To keep the bus from exploding and killing everybody on board they must jump the chasm. The question posed to my students is: can a bus actually leap over a 50-foot gap in a road? Together we will work through the physics of projectile motion to answer this question. In the movie the camera shows the bus moving a 70 mph at the time it reaches the gap in the road. We also need the angle at which the bus leaves the gap, upon inspection of the video the angle appears very small or not at all. If the bus leaves the roadway not at an angle the bus will never hit the other side because of gravity and the students will initially calculate the distance it will fall. The calculation is as follows

Vx = 70 mph =31 m/s
Δx = 50 feet = 15.2 m
$Vx = \Delta x/\Delta t$ therefore Δt = 15.2 m/ 31 m/s = 0.49 sec
$\Delta y = V_o \Delta t + ½ a \Delta t^2$ $a=g=9.8 m/s^2$
$\Delta y = ½(9.8 m/s^2)(0.49)^2$ = 1.18 m = 3.9 feet

This calculation shows that if the road does not have an angle of incline the bus will fall almost 4 feet below the roadway which would be about at the steering wheel of the bus.

Now, the students will work the problem with a small angle of incline say 2-3 degrees. In this case the students must first find the initial velocity in the horizontal and vertical directions. The calculation is as follows:

$V_x = V_o cos\theta = 31 m/s(cos 2^{o)} = 30.98$ m/s
$V_y = V_o sin\ \theta = 31 m/s(sin\ 2^o\ ) = 1.08$ m/s

The time to the highest point is
$V_f = Vo + a\ \Delta t$
$0 = 1.08 m/s + 9.8\ m/s^2 \Delta t$
$\Delta t = 0.11$ s therefore the time to return is the same so the total time of flight is 0.22-seconds

The horizontal distance the bus would travel in 0.22 s is determined to be
$\Delta x = V_x \Delta t = (30.98\ m/s)(0.22\ s) = 6.8$ m = 22.4 feet not the necessary 50 foot gap!

I will now have my students use the large white boards and pair up to answer the following questions in class. What is the minimum angle necessary to make the gap? If the bus did jump the gap at a 2^o angle what would be the minimum speed necessary to cross the 50 foot gap? The solutions to these questions are the minimum angle would be about 4.5 degrees and the minimum speed to make the jump at 2^o is about 103 mph. Both of these solutions are plausible at least for a car. All of these calculations are neglecting air resistance and the bus must be drivable after landing.[4] There is an additional projectile motion problem based on the movie *2 Fast 2 Furious* in the appendix.[5]

Another troubling aspect of watching the bus make this jump in the movie is for some unknown reason just before the bus hits the end of the road and propels itself into the air, it does a wheelie, and the wheelie helps the bus alter its trajectory to a much steeper launch angle then the roadway. While this adds to the drama of the scene how it can physically occur is a mystery. In the special features of the DVD the movie magic that made the bus jump appear possible is described in detail. The actual bus jump was made across a flat section of an overpass bridge. There was a specially designed ramp, with a kicker plate. The kicker plate is what propels the bus upward on take-off. After take-off the kicker plate falls and has no effect on the back wheels. The top of the incident ramp is about twelve feet (three meters) above the road. The bus was moving at around 60 mph upon leaving the ground and flew about 120 feet (30 meters) horizontally before landing. Upon landing the bus was not drivable suffering a broken oil pan, a flat tire and the broken doors.

The stunt driver was suspended in a special shock absorbing restraint to prevent serious injury and would have almost certainly broken his back upon landing. The bus was also specially modified removing any excess weight and moving the driver to the center of the bus to increase safety and make it easier to line up the jump on the ramp. The actual video footage of the bus jump is very unimpressive.

Newton's Laws

Newton's laws of motion allow us to determine the amount of force necessary to change an objects' motion. My students seem to always find elevator problems difficult to understand and solve. I am going to use the elevator fall introduced in the beginning of *Speed* to work through the problem to determining the force on the elevator cable and the people after a five story free-fall and quickly stopping. In the movie scene Dennis Hopper has planted several bombs on an express elevator in a 40 story building. In the loaded elevator during a decent Hopper detonates the first bomb and blows out the cable lowering the elevator at a safe speed. The elevator begins a free-fall but luckily the safety brakes engage and the elevator stops safely at about the 32 story. Hopper calls the police and request money or he will blow the breaks on the elevator sending the passengers to a certain death. Keanu Reeves and his side-kick Jeff Daniels come to the rescue and attach a steel cable from a building-top construction crane to the top of the elevator. When

Hopper blows the brakes the elevator drops about five stories before the cable catches and abruptly stops, then the cable crane breaks and the elevator drops another five stories before the crane which has become dislodged becomes stuck in the elevator shaft. The elevator and the passengers are unharmed but shaken. Is this possible?[6]

To determine the force acting on the elevator and on the people in the elevator we must first determine the speed of the elevator after falling five stories (approximately 15 meters). The following calculation show the final speed would be

$V_f^2 = V_o^2 + 2g\Delta y$
$V_f^2 = 0 + 2(9.8m/s^2)(15m)$
$V_f = 17$ m/s or 38 mph.

Then we must calculate the acceleration of the elevator upon quickly stopping. Acceleration is defined as the rate of change in the velocity and this elevator stopped very quickly lets say in about one-tenth of a second. (This can be determined by the number of frames the elevator was slowing to a stop and the frame speed of the movie.)

$a = \Delta v / \Delta t$
$a = 0\text{-}17m/s / 0.10\ s$
$a = 170\ m/s^2$

This value of acceleration is approximately 17 times the acceleration due to gravity or gs. The passengers of this elevator would feel as if they weight 17 times their own weight. A person's tolerance for acceleration depends on many factors including age and physical fitness. In general blackout from prolonged exposure occurs at about 5 gs and the chest acceleration experienced by Princess Diana during her fatal car wreck was approximately 70 gs.[7] The people in this elevator did not even fall to the floor at 17 gs and no one was even slightly injured.

The force on the cable is equal to the mass of the elevator (approximately 5000kg) times the acceleration in this case the net force would be

$F_{net} = ma$
$F_{net} = 5000\ kg(170m/s^2 + 9.8\ m/s^2)$
$F_{net} = 899\ 000$ N = 200 000 lbs

The net force on the average passenger would be

$F_{net} = ma$
$F_{net} = 70\ kg\ (\ 170\ m/s^2 + 9.8m/s^2)$
$F_{net} = 12600$ N = 2875 lb ! that is heavy

This is the amount of force each passenger would feel, I do not think the passengers would remain standing and many would break a bone or two. All the passengers crawled out of the elevator apparently unharmed.

Circular motion

Can our bus from the movie *Speed* make a 90^o turn at 50 mph? First a bus can not actually make a sharp 90 degree turn. To change direction by 90 degrees, the bus would have to follow a curved path. The bigger the circle the easier it will be to negotiate the turn successfully. From watching the scene it is hard to get the road's exact width, but it looks like the bus is traveling on a three-lane street, and turn onto a six-lane two way street, therefore the road get wider.[8] In addition, the road is unbanked therefore the only force providing the necessary centripetal force on the bus to negotiate the curve is static friction between the tires and the road. The coefficient of static friction between rubber tires and asphalt is approximately 0.80, so using Newton's second law we get the maximum possible static friction would be[9]

$F_{f\,max} = \mu_s F_N = \mu_s mg$

And the required centripetal force on the bus is found using

$F_c = mv^2/r$

Combining these two relationships the minimum radius of road the bus can negotiate without skidding can be determined to be

$\mu_s mg = mv^2/r$
$r = mv^2/\mu_s mg$
$r = 22^2 / 0.80(9.8)$
$r = 63.7$ m = 209 ft

Upon investigating the American Association of State Highway and Transportation Officials (AASHTO) standard for urban highway suggested the minimum radius of curvature for road speed of 50 mph is 1000 feet, which is five times this radius.[10] There is a high probability for the bus to negotiate a curve in the road successfully. In fact, The MythBusters tested if the "*Speed"* bus could make a sharp turn at a speed of 50 mph because Keanu Reeves had all the passenger move to one side of the bus to prevent the bus from turning over during this turn and found the bus could make such a turn and not turn-over even if the passenger did not move. [11] I will have my students watch this episode of MythBusters and we will discuss their excellent experimental design parameters. (Unfortunately this episode is from the 2009 season and will not be available for purchase until next year.)

Conservation of Momentum

In action-adventure movies, the gun fights can be as important as the side kick. Guns in action-adventure movies are able to do anything, firing shots that travel faster than the speed of sound without a sound or sonic boom, or throwing a normal-sized human across a room with a single shot usually through a sheet of glass. A moving car can throw an unfortunate pedestrian into the air so surely a gun would be able to produce an even more devastating blow on people. Can bullets throw you spinning into the air and still leave exit wounds? A bullet is a streamlined, small but hard object which focuses a large amount of kinetic energy into a small area and tends to go through objects instead of pushing objects about. By using the conservation of momentum the calculation the speed of a person after being shot by a large caliber gun will be determined.[12]

One example of a hero being blown off their feet by gun fire is shown in the movie *Lethal Weapon*, 1987. In *Lethal Weapon*, Sergeant Martin Riggs (Mel Gibson) stands on a sidewalk as a car approaches with a shotgun protruding from a window. Suddenly, he sees the gun but it is too late, he is blown violently off his feet and flies several feet backwards and upwards through the glass display window. Fortunately, Sergeant Riggs is wearing his bullet proof vest and survives. Example calculation of the conservation of momentum for Sergeant Riggs is as follows.[13]

m_{riggs} = 80 kg
m_{bullet} = 0.031kg
$\mathbf{v}_{bullet}$ = 350 m/s (typical bullet speed)

$\sum \mathbf{p}_{before} = \sum \mathbf{p}_{after}$
$(m_{bullet})v_{bullet} = (m_{riggs} + m_{bullet})v_{riggs}'$
$(0.03\ kg)(350\ m/s) = (80.03)(v_{riggs}')$
v_{riggs} = 0.13 m/s = 0.29 mph (a slow walk is about 1 mph)

Using the typical coefficient friction, μ_s, between shoes and his initial speed we will calculate the distance a person could move backwards before coming to a stop. The coefficient of friction between shoes and the floor is about 0.40.

The calculation of Riggs acceleration after being shot
$F_f = \mu_s F_N = \mu_s mg = (0.40)(80kg)(9.8m/s2) = 314\ N$
$F_f = ma$
$314\ N = 80a$
$a = 3.92\ m/s^2$

The calculation of the distance moved after being shop
$v_o = 0.13\ m/s$
$v_f = 0$

$a = 3.92\ m/s^2$
$v_f^2 = vo^2 + 2a\ \Delta x$
$\Delta x = 0.0021m$ or 2 millimeter backwards definitely not blow away.

There may be another possible explanation for a shooting victim being thrown backward by a bullet. The victim could be so stunned by being shot that they involuntarily tense his muscles, causing them to jump backwards. It is nearly impossible to jump or even step without bending your knees which would require a relaxing of the leg muscles not tensing of the muscles. In addition normal people can not jump backward by more than two or three feet (a normal small step) this distance is small compared to the backward leap caused by the bullet on Riggs in *Lethal Weapon*.[14]

The only way a bullet could make a person fall forward is if the person was already moving forward when they were hit by the bullet. This movie myth was also tested by the MythBusters in episode 25 and they proved that bullets can not blow people backwards.[15] A more realistic example of what bullets do to human when shot is shows in Steven Spielberg Oscar winning movie *Munich* but the violence is very- graphic and may not be appropriate to show in a high school classroom.[16]

Circuits

One of our most incredible technological accomplishments has been the development of the machines that can put people into space. The greatest of these achievements has been the successful Apollo moon missions in the late 1960's and 1970's. But there were several tragic accidents due to unanticipated technical errors. The Apollo 13 mission is famous for the dramatic and heroic attempt of the NASA scientist and astronauts to return the crew to Earth safely after a damaging accident.

The Apollo 13 mission has been effectively and dramatically portrayed by the 1995 film *Apollo 13* directed by Ron Howard. During what had become a "routine" Apollo mission to the moon an explosion occurred that sent the spacecraft into near disaster. The explosion in one of the oxygen tanks ripped a hole in the service module. In addition to having problems with the carbon-dioxide CO_2 level in the spacecraft, the explosion knocked out the fuel cells that were the prime source of electrical energy used to power the command module. The crew had to use the lunar module as a lifeboat until reentry to the Earth's atmosphere. However, prior to reentry the astronauts had to jettison the lunar module and return to the command module and use battery power to run the command module computer systems. Unfortunately, the way the circuits were configured mission control knew that there just was not enough energy to do the job. Therefore, mission control had to find a way to reconfigure the command module circuits and re-sequence the start-up such that the battery could provide sufficient energy to run the computer systems for reentry. In scenes 11 and 15 the director Ron Howard recreates mission control's intense efforts to find a solution the circuit problem using one of Apollo 13's most memorable ~~line~~lines by Ed Harris as Gene Kranz that "gentlemen, failure is not an option."[17]

I do not know the actual circuitry in the command module and it would be more complicated than I would want student to problem solve. I am going to use a simpler model to reenact the same exercise that mission control engineers had to go through to make the most of the energy available to them. My students using their understanding of simple electrical circuit analysis can get a feel for how the design of a circuit can affect the rate at which energy is used. The can also obtain a feel of what the engineering go through in finding a solution to a real problem, lots of trial and error the solution rarely is found on the first trial.

To get the Apollo 13 back home, mission control had to find a way to rearrange the circuitry to reduce the total current of the circuit from 60A to 12A, or reduce the power by a factor of five. My students will start with the following circuit running on a 60V battery as shown in Figure 1.[18]

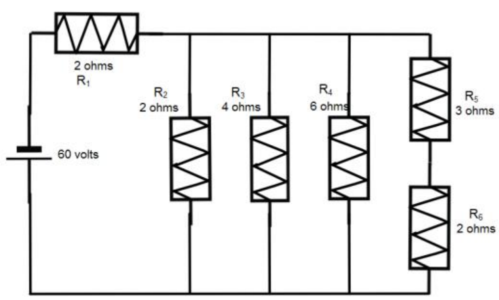

Figure 1 orginal circuit design

My students must now find the normal operating voltage and current in each resistor or circuit elements. The calculations are as follows: and begins by adding the R_5 and R_6 resistors in series which will result in a equivalent resistance of 5 ohms, all of the remaining resistors are in parallel except R_1 and the equivalent resistance for the parallel resistors is calculated as follows

$1/R_{eq} = 1/R_2 + 1/R_3 + 1/R_4 + 1/R_{eq56}$
$1/R_{eq} = 1/2 + 1/4 + 1/6 + 1/5$
$R_{eq} = 0.89\ \Omega$

Now, this parallel equivalent resistance is added to the final series R_1 to yield the total equivalent, R_{eqt}.

$R_{eqt} = R_{eq} + R_1$
$R_{eqt} = 0.89\Omega + 2\Omega = 2.89\Omega$

Using Ohm's law the students will calculate the current using the total equivalent resistance.

$V = IR$
$60V = I_t(2.89\Omega)$
$I_t = 20.8$ A

And the total power for the circuit is

$P = VI$
$P = 60V(20.8A)$
$P = 1250$ W.

To determine the voltage and current through each resistor we can use Ohm's law individually to each resistor. The calculations are as follows

$V_1 = I_tR_1 = 20.8A(2\Omega) = 41.6$ V.

This leaves 18.4V(V_p) across each of the parallel branches of the circuit. We can now determine the current through each of the parallel branches as follows.

$I_2 = V_p/R_2 = 18.6\text{ V}/ 2\Omega = 9.2\text{ A}$
$I_3 = V_p/R_3 = 18.4\text{ V}/ 4\Omega = 4.6\text{ A}$
$I_4 = V_p/R_4 = 18.4\text{ V}/ 6\ \Omega = 3.1\text{ A}$
$I_{5\&6} = V_p/R_{eq56} = 18.4\text{ V}/ 5\ \Omega = 3.7\text{ A}$

Finally, because R_5 and R_6 are in series the voltage is divided but the current is the same the individual voltage drops are

$V_5 = I_{5\&6}(R_5) = 3.7\text{ A}(3\Omega) = 11\text{ V}$
$V_6 = I_{5\&6}(R_6) = 3.7\text{ A}(2\Omega) = 7.4\text{ V}$

The challenge for my students will be to redesign this circuit to reduce the power by half; if the power is reduced in half the circuit can now operate for twice the amount of time. By reducing the power they must reduce the current by half or have no more than 10.4 A of current in the circuit. If the current is now 10.4 A the equivalent resistance must not be less than 5.8 Ω. To increase the equivalent resistance more resistors must be place in series in the circuit. The students must be careful not to place all the resistors in series because you can reduce the current by too much and each element can not function with a current at less than half the original value. The circuit diagram shown in figure 2 will meet these goals and the calculated voltages and current are show below this may not be the only possible circuit arraignment that will meet the power requirements.

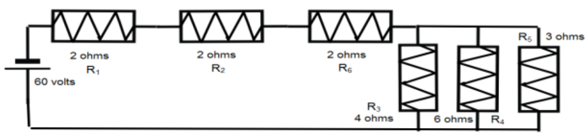

Figure 2 circuit design using half the power

If the students will find the equivalent resistances of the three resistors in parallel which is found to be

$1/R_{eqp} = 1/R_3 + 1/R_4 + 1/R_5$

$1/R_{eqp} = 1/4\Omega + 1/6\Omega + 1/3\Omega$

$R_{eqp} = 1.33\Omega$

Now this resistance is added to the three resistors in series to find the total equivalent resistance

$R_t = R_1 + R_2 + R_6 + R_{eqp}$

$R_t = 2\Omega + 2\Omega + 2\Omega + 1.33\Omega$

$R_t = 7.33\Omega$

Now the total current can be calculated using ohm's law and the power necessary to run the circuit.

$V = I_t(R_t)$

$60\ V = I_t(7.33\Omega)$

$I_t = 8.2\ A$

Which is slightly less than half the original circuit's current.

$P = VI$

$P = 60V(8.2A)$

$P = 429\ W$ less than half the original power

The current through each of the resistors in series is the same as the total current of 8.2 A which is enough current to run those devices, the current through the parallel combination is divided the voltage is the same and is computed to be 10.9 V which lead to 2.7 A through the 4Ω resistor, 3.6 A through the 3Ω resistor and 1.8 A through the 6Ω again enough current for operation.

Student Project

Students generally view science as simply a subject studied in school and a requirement for graduation. Science sometimes shows up in the "real" world in the form of technological or medical advancements and has no personal connection. I want students to realize that science is everywhere in their lives even in the movies and television they watch. By watching bad or good movie science it can effect their perception of how the universe works.[19] The students have now been exposed to good and bad movie physics examples. They have solved problems related to most of the objectives studied in an introductory physics course and it is their turn to find movie physics examples. The students will pair up in a team to find their own science in an action-adventure movie. I am limiting the students to action-adventure movies because by their nature they must abide by the laws of nature. The students will select a movie scene, analyze the physics and present their finding to the class. The student instructions and a presentation rubric are given in appendix ~~2~~ 2.

Notes

[1]Brecht, Bertolt. *Galileo* (New York: Grove Press, 1966), 78.

[2]NC Standard Course of Study. *North Carolina Public Schools*, http://www.dpi.state.nc.us/curriculum/.

[3] *Speed (Widescreen Edition)*. DVD. Directed by Jan De Bont (Tucson: 20th Century Fox, 1994).

[4]Weiner, Adam. *Don't Try This At Home!: The Physics of Hollywood Movies (Science)*(New York Coty: Kaplan Publishing, 2007) 12.

[5]*2 Fast 2 Furious (Widescreen Edition)*. DVD. Directed by John Singleton (Washington DC: Universal Studios, 2003).

[6] *Speed (Widescreen Edition)*. DVD. Directed by Jan De Bont.

[7]Rogers, Tom. *Insultingly Stupid Movie Physics* (New York: Sourcebooks Hysteria, 2007) 158.

[8] *Speed (Widescreen Edition)*. DVD. Directed by Jan De Bont.

[9] Weiner, Adam. *Don't Try This At Home!: The Physics of Hollywood Movies (Science)*,97.

[10] "Knovel - display." Why Knovel?. http://knovel.com/web/portal/browse/display?

[11] Hyneman, Jamie, and Adam Savage. "MythBusters : Episode Guide : Discovery Channel." Discovery Channel : Science, History, Space, Tech, Sharks, News. http://dsc.discovery.com/fansites/mythbusters/episode/episode.html, episode 115 season 7. .

[12] Rogers, Tom. *Insultingly Stupid Movie Physics*, 183.

[13] *Lethal Weapon (Director's Cut)* DVD. Directed by Richard Donner (Burbank: Warner Home Video, 1987).

[14] Rogers, Tom. *Insultingly Stupid Movie Physics*, 184.

[15] Hyneman, Jamie, and Adam Savage. "MythBusters : Episode Guide : Discovery Channel." Discovery Channel : Science, History, Space, Tech, Sharks, News. http://dsc.discovery.com/fansites/mythbusters/episode/episode.html, episode 25.

[16] *Munich (Widescreen Edition)*. DVD. Directed by Steven Spielberg (Washington DC: Universal Studios, 2006).

[17] *Apollo 13 (Widescreen Collector's Edition)*. DVD. Directed by Ron Howard (Washington DC: Universal Studios, 1995).

[18] Weiner, Adam. *Don't Try This At Home!: The Physics of Hollywood Movies (Science)*,161.

[19] Greene, Brian. "Put a Little Science in Your Life." *New York Times*, June 1, 2008, sec. Sunday Opinion.

Appendix 1

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Annotated Bibliography

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Tom Rogers web site that is a summary of the book of the same name.

Rogers, Tom. *Insultingly Stupid Movie Physics*. New York: Sourcebooks Hysteria, 2007.
Describes in detail commonplace physics principles as they are displayed in Hollywood movies. Tom Rogers has developed a rating system for bad physics displayed in movies and has a companion web site that lead to the book

Weiner, Adam. *Don't Try This At Home!: The Physics of Hollywood Movies (Science)*. New York Coty: Kaplan Publishing, 2007.
A text book that teaches physics concepts through the use of movies. A very unique method to teach physics.

2 Fast 2 Furious (Widescreen Edition). DVD. Directed by John Singleton. Washington DC: Universal Studios, 2003.
Former cop, Brian O’Conner, is finally arrested and he must now work with an old college friend to help the police arrest a local drug exporter. Has a great bridge jump scene.

Apollo 13 (Widescreen Collector's Edition). DVD. Directed by Ron Howard. Washington DC: Universal Studios, 1995.
The movie recreates the near disaster of the Apollo 13 moon mission. A short circuit caused a spark to ignite inside one of the oxygen tanks, causing a major explosion in the service module. The astronauts were forced to shut down power and relocate to the lunar module where they hoped there would be sufficient life support to bring them home.

Lethal Weapon (Director's Cut). DVD. Directed by Richard Donner. Burbank: Warner Home Video, 1987.
A veteran cop played by Danny Glover is partnered with a young homicidal cop, Riggs, played by Mel Gibson must learn to work together to stop a gang of drug

smugglers. Has several building jump scenes and Riggs is blown away by a bullet.

Munich (Widescreen Edition). DVD. Directed by Steven Spielberg. Washington DC: Universal Studios, 2006.
Based on the true story of the Black September aftermath. The film begins with a realistic depiction of the events of the Munich Massacre in 1972. After the killing the Israeli government retaliates. Very realistic killings.

Speed (Widescreen Edition). DVD. Directed by Jan De Bont. Tucson: 20th Century Fox, 1994.
Ex-police demolition expert out to get revenge terrorizes a city with hidden bombs. Great action scenes including the famous bus jump.

Appendix 2 Student handouts

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Physics in Films Student Handout

Physics in Phyilms Project

Objective: The student will work with a partner and be able to analyze a physics principle displayed in an action-adventure movie and present their findings to the class. Students generally view science as simply a subject studied in school and a requirement for graduation. I want students to realize that science is everywhere in their lives even in the movies and television they watch. By watching good or bad movie science it can effect their perception of how the universe works.

Student Name______________________________

Partner Name_______________________________

Movie ___________________________________

Movie rating (circle) PG PG13 R If the movie is R-rated you **must** have a parent signature.

A short description of the scene being analyzed and the physics principle

____
____
____
____

Teacher's signature___________________________________

Parent signature______________________________________

Note to parent: Your child has an assignment to find a physics principle displayed in an action-adventure movie. I have movies available to students to use or they may use their own movies they are not required to purchase any movie. If they choose to use an R-rated movie your child is required to have you sign this form approving it is acceptable that you son or daughter ~~use~~ view an R-rated movie. The selected scene can not show nudity but may have violence or use profanity due to the nature of the action-adventure movie genre.

Physics in film Project Rubric						
Assignment: Communicate complete information on movie physics using a scene video clips or advanced features from an action-adventure movie.						
	Beginner: 1 point	Novice: 2 Points	Intermediate: 3 points	Expert: 4 points	Self Evaluation	Teacher Evaluation
Topic/Content	Includes little essential information and one or two facts	Includes some essential information with few facts.	Includes essential information Includes enough elaboration to show basic Understanding of the physics.	Covers topic completely and in depth. Goes beyond basic understanding of the physics principles.		

Technical Requirements	Includes, few physics facts	Shows limited application of knowledge of the physics principal described	Includes essential application of the physics principle described.	Included a complete application of the physics principle described		
Mechanics	Includes more than 1 mathematical or physics analysis errors	Includes 3-4 missing units or formula but application of physics is ok.	Missing units or formula in application of the physics.	No math or application errors all units and formula included		
Cooperative Group Work	Cannot work with others in most situations.— . . Cannot share decisions or responsibilities.	Works with others, but has difficulty sharing decisions and responsibilities.	Works well with others. Takes part in most decisions and contributes fair share to group.	Works well with others. Assumes a clear role and related responsibilities. Motivates others to do their best.		
Oral Presentation Skills	Great difficulty communicating ideas.— . . Poor voice projection.— . . Little preparation or incomplete work.	Some difficulty communicating ideas, due to voice projection, lack of preparation, or incomplete work	Communicates ideas with proper voice projection. Adequate preparation and delivery.	Communicates ideas with enthusiasm, proper voice projection, appropriate language, and clear delivery.		
Scale: 18 - 20=Expert 15 - 17=Intermediate 10 - 14=Novice 6 - 9=Beginner				Total Points		

Notes

Addition Student problems

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Projectile motion

In the movie *2 Fast 2 Furious*, two cars are racing toward a raised bridge at a high rate of speed. They must jump the gap because a lift bridge makes a steep ramp for take-off the jump seems plausible. If the initial speed of the front car is 130 mph at the edge of the ramp and the second car is going 160 mph, which car hits the far side of the bridge first? What happens in the movie? Is there a problem?

Circular motion

It would be a lot easier to make a 90-degree turn if the road were banked. Explain why a banked road makes it easier to go around a curve. Draw a force diagram to illustrate this point. What is the agent that acts as the centripetal force in this case?

There is an amusement park ride called the "Graviton" shaped like a ring. It spins in a circle with the passengers pressed up against the wall. When it reaches a certain speed the floor falls away and the passengers are stuck to the sides of the ring. Explain how this ride works.

If the "Graviton" has a radius of 5 meters, and a coefficient of static friction between the wall and clothing of 0.5, what is the minimum speed that the ring must go so the riders do not slide down the wall?

Conservation of momentum and energy

In an off-screen moment during the filming of MI-II Tom Cruise and Dougray Scott are rehearsing their motorcycle scene by carefully jogging into each other. In one particular attempt they are both moving a 4 m/s before colliding and they bounce off of each other. As a result Cruise is sent moving backward at a speed of 3 m/s. How fast and in what direction is Dougray Scott moving just after the collision?

Appendix 3

North Carolina Department of Public Instruction Physics objectives addressed in this curriculum unit.

General Science Objectives

Allow students to brainstorm ways that technology can be used to enhance scientific study in the future.

Encourage debate about these resolutions and their consequences

Physics Objectives

2.03 Analyze acceleration as rate of change in velocity

2.04 Using graphical and mathematical tools, design and conduct investigations of linear motion and the relationships among: position, average velocity, instantaneous velocity, acceleration, time.
3.01 Analyze and evaluate projectile motion in a defined frame of reference.
3.02 Design and conduct investigations of two-dimensional motion of objects.
3.03 Analyze and evaluate independence of the vector components of projectile motion.
3.04 Evaluate, measure, and analyze circular motion.
3.05 Analyze and evaluate the nature of centripetal forces.
3.06 Investigate, evaluate and analyze the relationship among: centripetal force, centripetal acceleration, mass, velocity, radius.
4.03 Assess, measure, and calculate the relationship among the force acting on a body, the mass of the body, and the nature of the acceleration produced (Newton's Second Law of Motion).
5.04 Analyze one-dimensional interactions between objects and recognize that the total momentum is conserved in both collision and recoil situations
5.05 Assess real world applications of the impulse and momentum, including but not limited to, sports and transportation
8.02 Analyze and measure the relationship among potential difference, current, and resistance in a direct current circuit.
8.03 Analyze and measure the relationship among current, voltage, and resistance in circuits, in series, parallel, series-parallel combinations.
8.04 Analyze and measure the nature of power in an electrical circuit.

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