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See You in the Funny Pages: Attempting to Rectify Student's Long-Standing False Intuitions of Engineering Science

Francis A. Di Bella, P.Eng.

ABSTRACT

Present and future engineering technology students have been in a long standing, subliminal educational environment that is effecting their intuition as regards the physical laws of science and engineering. That environment consists of their exposure to not only science fiction and science fantasy films but also daily newspaper comics featuring non-engineering characters (even Dilbert has been a culprit in this deception) and summer-adventure movies starring their action hero actors who 'can-do-no-wrong". This exposure results in a subliminal effect on what the young boy or girl understands is the way the universe works. For example, actors are seen swinging from the middle of a rope bridge that is over 100 ft long only to survive the crash against the steep sides of the cliff. In reality the swing from such a height is equivalent of jumping from a 50 ft tall building and expecting to survive! While it is certainly entertaining to see the hero of the film survive, the unintended message that the stunt delivers is that the laws of physics are different than what they are in reality. What was once a bending of the physical laws of the universe in animated films has now been expanded to adventure films with human actors who enjoy the exaggerated use of computer derived special affects.

This paper sites other several examples of this false instruction and suggests that this subliminal instruction into the laws of physics is resulting in a reduction in the intuition for our future engineering students. The subsequent re-instruction of the actual engineering physics becomes a much more difficult chore for engineering instructors. The paper also illustrates how such sources of miss-information can be used to entertain and educate the engineering student in the reality of the physical laws.

Although the pedagogy described in this paper has not been adopted as part of the general curriculum for instructing engineering technology students at Northeastern University, it has been successfully used by the author. That success has been measured by the student's enhanced reception and interest to these case study problems that are worked-out in the author's Mechanical Engineering Technology courses. The case studies are usually good examples of Feasibility Analysis in Dynamics, Stress Analysis, Introduction to Fluid Dynamics, Thermodynamics and Heat Transfer. The students find these examples to be an interesting diversion from the typical "real world" examples and/or Case Studies that are typically used for instruction. The result is not only a more entertaining presentation but also a lesson in feasibility analysis applied to a problem that

the students usually assume is already "feasible" given the authority: the printed page or live-action cinema. The lesson quickly reveals that short-comings of not preparing a valid feasibility analysis.

Introduction

The very old admonition to "…see you in the funny papers" was often said as two or more people begin to depart having had a pleasant discussion on any number of subjects. Like most good salutations it probably had a variety of meanings depending on the context it was given. The author's interpretation of this phrase is perhaps too philosophical in that the phrase could suggest that sooner or later everyone will have their "15 minutes of fame" and that this fame could be in the funny (comic) pages of the newspaper as well as any part of the legitimate press. But there was also the strong hint that the "funny' pages was the likely repository of some very basic human truths; perhaps hidden under the surface of the intended humor…but it was there and could be found if searched for long enough.

It is with this later meaning that this conference paper makes a very bold statement that has been stated before by others in a variety of informal discussions about the direction of engineering education in the 21st century. The comic pages and now more recently the legitimate cinema have bent the laws of physics in such a believable fashion with live actors and not animated characters that young movie goers have not been able to separate real physics from cinema illusion. As innocent as this may seem, engineering instructors can sympathize with this author's observation that some engineering students do not have a physical intuition for how the real universe behaves. For example, most students know that an object will fall with a constant acceleration. However, the viewers of such movies such as "The Matrix" or "Kill Bill" may believe that the time it takes to leap six feet into the air and fall to the ground is enough time for 4 axial spirals, power kicks without "…equal and opposite reactions", and body turns without external applied forces. This deficiency hinders their ability to solve a multi-step, engineering problem.

The author is not suggesting that this is a recent development[1] but only that it seems to be getting worse in the frequency of infractions that occur in the comics, movies or TV. But there is good news also. The same medium can be used to rectify the problem while still enabling the Instructor to provide an enlivened and maybe even an entertaining education for his/her engineering students. More specifically, the instructor must search for such infractions (even if it means going to some bad movies or sitting through some poor TV programs), bring them into the classroom to be dealt with face-to-face and re-engineer the problem by correctly applying physical laws to expose the physical fallacies. The good news is that the Instructor can count on the fact that a majority of the students have already seen the illusions and have had their attention focused on the "problem" even if subliminally, for one or two hours (depending upon the length of the movie or TV). Thus there is some level of recall by the students of their favorite movie or TV

[1] The author remembers fondly the '60's movie "Flubber' staring Fred Mac Murray as the absent minded Professor who accidentally discovers a material that …the author now understands…violates the First law of Thermodynamics; even though the professor does remember the correct sign for the enthalpy equation immediately after the explosion!

action scene. Thus, one of the Instructor's most important tasks: getting the interest of the student, has already been accomplished…thank you MGM, Disney, ABC, NBC and CBS.

Examples of Some Sources of Inspiration of 'real-world' engineering examples from the Entertainment Media

From the movies No. 1: Indiana Jones and the Temple of Doom
The Indiana Jones trilogy is great entertainment and it is not this author's intention of reducing this entertainment value or suggesting that the movies should not be an innocent means of escapism. It is a prime example of the author's treatise however, because this fun adventure movie has human actors (i.e. not animated cartoon characters) and with more than just a little suspension of physical reality, these actors can do most anything with impunity. With impunity that is except that some of the younger (and even some older) movie goers start to learn the wrong physics.

Consider two scenes that occur at the end of the movie as cases in point

Scene 1.
The hero Indiana Jones is caught between two enemy forces on either side of a rope bridge that is suspended (approximately) 100 yards across a deep chasm. As the troops proceed to close-in on their prey, Indiana Jones decides that the only way out of this trap is to hold on to the rope bridge while he cuts through the two supporting cables. Yelling to his colleagues to hold on to the cables, the bridge ties are severed and the bridge half that Indian Jones holds on to swings as expected until the Jones comes crashing against the shear walls that make up the sides of the deep chasm. The enemy forces all fall into the ravine. After the proper amount of hand-to-hand combat with the antagonist of the story, Jones pulls himself up from using what remains of the rope bridge.

It is likely that most readers have seen this movie scene and thus the description that is put forth here need not be more detailed. And there-in lays one of the benefits of this author's proposal. It is very true that a majority of the young and old movie audience have also seen this fine movie, including therefore future engineers and technologists that will be sitting in the classroom. Therefore, from the stand point of the Instructor much of the ground work for describing this scene and its reality is already imbedded in the minds of these future technologists who may now sit in your classroom waiting to be entertained with enlivened education.

The physics of the problem is evident upon close inspection. Swinging from a rope that is ½ x 100 yards is equal to falling from a height of 150 ft or from approximately a 10 story building! It is likely that the antagonist, who Jones defeats after the swinging has stopped, probably would have survived because he was only approximately 10 ft from the anchor point while Jones in reality would be dispatched to other unearthly, adventures. Certainly the author is not suggesting that this physical reality be adhered to by Hollywood for then how could the forces of "evil" be defeated by the forces of "good" and still be entertaining! What this author is suggesting is that such Hollywood distortions are the perfect venue for instructing students who have had their attention focused onto a 'real-world" application of the engineering physics that we are trying to teach.

Before leaving this scene, another observation must be made. Prior to cutting the bridge cables the movie go-er is held in more suspense by Hollywood. The rope bridge is depicted as being worn and almost ready to fall apart. Several of the wooden slats easily break as the young boy in the movie attempts to use the bridge. What is the consequence of the bridge being cut? Indiana Jones hopefully is intelligent enough to hold onto the rope cables and not the worn wooden slats. At an angle of 20 degrees from the horizontal the wooden slats have a force equal to the weight of Mr. Jones but as the rope completes it's arc (i.e. becoming vertical) Mr. Jones' weight is multiplied by a little more than 3 times due to the centripetal force! If the rope and/or the wooden treads cannot take this force then the bridge will fail. Even more interesting to ponder is the total force exerted on the anchor point (hopefully in solid rock) by the sum total of the centripetal forces from all of the other "holders-on".

Scene 2
In an earlier scene, the heroes of the movie are trying to escape from the Temple of Doom using an aged coal, railroad car and the most fantastic roller coaster-like track ever devised. First, congratulations are offered to the civil engineers who designed and constructed this winding and tortuous track within the close confines and the deep and dark bowels of the Temple of Doom mountain.

Having escaped the villains, the coal car must now be safely stopped before it crashes into the wall of the mountain at the end of the track. Indiana Jones quickly uses his foot against the spinning railroad wheel to stop the speeding rail car when the handbrake fails. If this author is correct in his assumption that this scene is all too familiar to the reader then the point about "…the focussed attention of a mass audience" has been made..

But at what sacrifice to physics and the intuition of the future engineering technologists?

The stopping of the rail car using the hero's foot would require that the kinetic energy of the rail car be absorbed by Mr. Jones. A little engineering physics: conservation of energy indicates that Indiana Jones has been incinerated as the kinetic energy of the rail car and its contents is converted to stored internal energy in the form of elevated temperature.

This author suspects that the engineering-types among the readers are quick to point out that perhaps all of the kinetic energy did not get absorbed into Jones feet but that some of the energy was lost via convection cooling due to the speed of the rail car. To this the author says: "Congratulations, you are now seeing the potential of this "real-world" application of engineering physics and technology to Hollywood theatrics." The instructor must indicate that the student should make assumptions regarding the nature of the problem; particularly if this allows an easier solution. Several ways of solving the problem should be tried by the Instructor and/or the student assisted by the Instructor.

The point in the exercise is to have the students start using their new-found engineering "tools" in the solution of engineering problems that are all too familiar to them.

The author suspects the reader may be asking: "What 'real-world' engineering problems…swinging rope bridges and out of control rail cars?"

In fact, the proposed pedagogy uses the proven "brain storming" technique of using analogies to help creatively solve a variety of engineering problems.

Where some may see only an adventure hero walking away from a swinging bridge after a 150 ft fall, this author contends that the students should be made to see that the 150 ft. fall may be an emergency evacuation system from a high rise building that the engineer must design. The run away rail car is even easier. What brake material should be specified for this rail car…or in fact for any automobile if the brake assembly must not get above 175 F.? Anyone who has been to the Rocky Mountains and has started the decent from the high peaks knows that there are "rest" stops for the vehicle and temperature gauges available to monitor the brake and wheel assemblies for vehicles attempting to safely make the descent. The students need to be made aware of these 'real-world" applications of these Hollywood moments.

Similarly, the "real-world" application of the centripetal forces that have compounded to tug at the cable at the anchor point (see scene 1) is no different than the failure mode for the Hyatt Regency walk way collapse that is touted in many engineering classes as not only a lesson in stress analysis but ethics as well.

Thus, each of these Hollywood infractions can serve as a sounding board for "real-world" engineering applications. The Instructor must grasp this opportunity while the student's interest is still high.

From the Movies No.2: The Case of the Disappearing Car
The following movie escape scene has been witnessed by the author in several different movies. The physics doesn't change only the actors.

The heroes of the movie are being chased by the police and/or the movie's antagonists. They have just absconded with a king's ransom worth of valuables (cash, jewelry, paintings, kidnapped mafia chieftain…remember: the booty changes, but not the physics!). They are in a muscle, sports car that has succeeded in speeding onto a major highway where they put into action the final part of their escape plan. A tractor-trailer, driven by the partners of the escapees, leads the way along the highway. At the precise moment the back doors of the trailer open and two ramps are seen extended from the rear opening. The ends of the ramps are anchored to the foot of the trailer door and the other ends are stretched out and roll along the highway with the tractor-trailer at the speed limit (no sense in getting a speeding ticket now!). The muscle car approaches the tractor-trailer at a high speed (assumption here: 65 to 75 mph) and smoothly maneuvers first the front wheels and then quickly the rear wheels onto the ramp and then come skidding to a stop within the trailer without hitting the front end of the trailer. Once inside the rear doors of the trailer are closed and the sports car is no where to be found on the highway. The rapidly approaching antagonists lose sight of their prey and pass the unsuspected tractor-trailer.

This is a very thrilling live-cinema action stunt! But exactly how long is this "unsuspected" trailer anyway? Assuming that the sports car is moving with a speed of 75 mph and catches up to and enters the tractor-trailer that is moving at only 65 mph (remember the speed limit constraint) and assuming that all four wheels lock up (coefficient of friction equal to 0.4) to stop the sports car, then the stopping distance is 117 ft. To have the sports car stop within the trailer without hitting the dead-end, the sports car would need to have an initial speed of about 68 mph or only 3 mph more than the trailer.

Here again the instructor can have some fun playing with a variety of assumptions for relative speeds or front wheel vs. rear wheel braking effects or even the use of energy storage devices in the trailer such as springs or mattresses.

From the Movies No. 3: Robo-Cop 1

The following example is offered as an example of how techno-science fiction can seamlessly confuse fiction from physics fact. Even when the audience is relaxing and has suspended reality to believe that a robot could be manufactured in the image and parts from a human police officer (in this movie the "80-20 rule" has been altered when approximately 98% of the Robo-Cop is robot and only 2% remains "cop"), Hollywood makes a subtle error that has, at least in this author's belief, subliminal, long-term effects on the viewer.

The offending scene occurs when the Robo-Cop is on his first excursion from the laboratory. He interrupts a liquor store hold-up where two thieves armed with long barrel shotguns are in the process of stealing the nightly cash proceeds. In comes the Robo-Cop to the amazement and puzzlement of the shot-gun toting thieves. Instinctively, the thieves each point their weapons toward the Robo-Cop intruder and threaten him with extinction. Equally instinctively but much more quickly, the Robo-Cop reaches for each of the shot gun barrels and easily bends the barrels upward at a 90 degree angle, thus rendering the shot guns harmless. The hold-up is foiled, the viewing audience is amazed at the strength of the new hero and the movie continues to other similar heroic adventures.

But not before the audience has been subliminally and forever affected by the notion that "…every force *may or may not* have an equal and opposite reaction"; with apologies to Sir Isaac Newton who stated one of the main stays of engineering physics and universal law: Newton's Third law of Motion.

In reality, if the shot gun barrels can be easily bent upward by the Robo-Cop hero then in order for the shot guns not be wrenched from the hands of the would-be hold-up men or, if the grasp is truly secure, either the bones in their fore arms break or they are lifted off the floor. Then again, perhaps the men are able to counter the force and moment that the

Robo-Cop was administering. In that event it may be argued that the thieves are as strong as the hero and given that there are two of them, the Robo-Cop could have been defeated in a subsequent hand-to-hand fight.

But how would this effect a future engineering student?

A future engineering student who witnessed this short scene may be perplexed by the premature failure of the solid-looking bracket before the affixed was loosened. Perhaps a future architect who has remembered this scene will not bother to check the strength of the masonry that he/she specifies to support a cantilevered beam; a beam which has otherwise been properly sized for a concentrated or distributed load.

From the Comics

The world of comics is ripe with examples of intentionally exaggerated physically unrealistic systems. Once again this author does not intend to slight the very creative artists, humanists really, who prepare these comics as welcomed diversions from the worldly news. In fact, the author is careful to point out to his engineering design students that there are many instances where the comics are great sources of inspiration for new products. After all the comics illustrator and creative artist is trying to relate to the human condition in a humorous way perhaps, but never the less expresses some human need or desire. From this point of view, the comics can be looked at as a veritable storehouse of marketing opportunities.

They are certainly a veritable "gold mine" of real-world applications of engineering technology physics.

Consider the following examples.

FOXTROT by Bill Amend[2]
A perfect example of the author's thesis is in a cartoon prepared by Mr. Bill Amend in his strip called Foxtrot. In a Sunday paper edition where larger illustrated panels are an available option a June installment reveals the strip's two young boys (Jason and his faithful companion Artemus) are comfortably suspended in the air by streams of water exiting from countless water hoses that are all connected to the house water supply. From their vantage point 10 ft in the air, they can tease Jason's sister who is relegated to suffering from the hot summer sun on the ground. Meanwhile, the reading audience's attention is also made to focus on the unsuspecting Dad who is attempting to fill a water glass from the kitchen sink only to find that the water pressure has virtually disappeared.

On a hot summer day and perhaps also lounging comfortably, the Instructor can prepare the next two lessons in fluid dynamics and mechanics (statics) from one humorous cartoon. The engineering questions to be solved (with suitable assumptions made) are:

[2] The Creator of the comic strip FOXTROT, Mr. Bill Amend is in fact a techno-file at heart as evidenced by his characters who glamorize the technical intellectual types. His efforts to emphasize the attractiveness of a technical curiosity in his characters are much appreciated.

1. What velocity must be impinging on the boys to hold the boys?
2. What is the velocity at the exit of the hoses?
3. What is the pressure in the hose at the inlet of the water nozzles?
4. What is the mass flow rate of water from the 10 hoses?
5. What is the necessary water pressure from the street water supply to sustain this inventory of water?

From the Comics Foxtrot No. 2

Another cartoon from the same author has the same two boys dueling with water pistols at 20 ft in a very hot summer day. The only problem is that the day is so hot that the water spritzing from each water pistol immediately evaporates before reaching the intended targets. Exactly how hot is it anyway and how much water is being shot out of each pistol?

This is a mass diffusion and heat transfer problem. But does it have a "real-world" application?

Certainly! In the real-world of heating, ventilation and air conditioning engineering (HVAC) there is a need to determine the size of a wet cooling tower for a given amount of heat dissipation. But there is also a need to estimate how much water will be "slipped" into the cooling ambient air during this direct contact heat exchange. Different application? Yes. But the same equations and the drawings are available at the cost of the newspaper.

Conclusion

There are many such applications that can be garnered from Hollywood or the newspapers and that can serve the purpose of educating future engineering technologists and the public. By using the fact that the public's attention has already been focused on a subject that is common place, the instructor can then take over and use this focus to educate, with in an enlivened and entertaining manner, some very relevant engineering principals. This has the effect of not only empowering the student with an understanding that everyday problems can be resolved with what they have learned from within the confines of an engineering classroom, but that what they are solving has broader applications. The same equations (after all there are truly only about 15 universal laws anyway) can be applied over and over again to different applications.

Once this is realized by the students the task of learning the subject material is made easier for the student just as the task of teaching the subject material is made easier for the Instructor and, frankly, much more fun for both!

This paper has presented the basis for an NSF proposal that will be submitted in the Fall, 2005. The proposal will formally outline the assessment tools that will attempt to quantify the improvement in the student's inherent intuition to solving an engineering problem once the sources of false intuition are, if not eliminated, than subdued.

Biography:
Francis A. Di Bella, P.Eng. is an Assistant Professor, Northeastern University, Boston, MA.; College of Engineering , School of Engineering Technology. Mr. Di Bella's professional engineering research interests involve the practical, engineering applications of Thermo-fluid and Machine Design sciences within the Mechanical Engineering discipline.

Specific areas of interest include all aspects of energy systems including generation, storage, conservation and a variety of innovative applications of renewable energy including thermal air chimney integrated with solar energy, wind turbines integrated with ocean wave power generating systems, classical solar and hydropower as well as advanced hybrid vehicles using turbo charger-generator concepts to improve range or increase load. All of these interests are exhibited in course instruction in heat transfer, thermodynamics, fluid dynamics via the case study methodology.

Prof. Di Bella is also involved in all aspects of creative product concept genesis, design and product development. Product development extends the gamut from systems to prevent Road Rage to emergency repair of ruptured natural gas pipelines. University application of this interest includes instruction in the following courses: Machine Design, Statics and Dynamics, Intro. to Design and Intro. to Product Design as well as student Capstone Design Projects. He is also the Faculty Advisor for the Student's Mini-Baja vehicle competition. He and his colleagues have instituted a Capstone Senior Design Project course for engineering technology students that includes an integrated group of Computer, Electrical and Mechanical Engineering Technology students. He has also structured an Intro. to Product Design course for non-engineering majors as part of the University's new School of Technological Entrepreneurship .

In 2002 Prof. Di Bella was awarded the University wide Excellence in Teaching Award for his innovative contributions to the teaching of engineering students. He was awarded the College of Engineering Excellence in Teaching Award in 2004.