Roller Derby as an Instructional Tool to Engage Physics Students
Or:
How I Learned to Stop Worrying and Love the Track

by
Amanda L. Dolan

Submitted in Partial Fulfillment
of the Requirements for the Degree

Masters of Physics Education

Supervised by
Dan MacIsaac

Department of Physics

State College at Buffalo
Buffalo, New York

2013

Abstract

Drawing connections between the classroom topic and activities in our students' lives is a powerful tool for gaining and maintaining student motivation. Using sports to illustrate different physics principles is a helpful tool to increase student engagement. Typically, most sports mentioned in physics practice questions and explanations are traditionally male sports. Roller derby is the perfect sport to help physics teachers break out of this mold. Using personal experience as well as new data, I will show how various concepts from the Regents physics curriculum can be explored through the sport of roller debry.

Acknowledgments

Dan MacIsaac
Tata Pain
Shockin' Audrey
Kelly Pearson
VenJence Von Slay
Lauren Cocilova
Brie McCulley
Dan MacIsaac
Tae Cook
J'Boodie
Lynn Patriquin
Debbie McFearson
Toxin Dioxin
Resident Eva
Wolf Blitzkrieg
Roc City Roller Derby
Emmeline Spankhurst
Dani/Random Dent
Asa Clubs
Muffy
Sam Waters
Grand Poobah
Kathy Lee

Table of Contents

Abstract
Acknowledgements
Introduction
Literary Review
Introduction to Roller Derby
Experimental Equipment
The Physics of Roller Skating
Falling and Stopping
Conclusion
References

Introduction

Sports are an excellent way to teach physics principles. In a study by Hatch and Smith (2004), physics and sports were merged and students showed very positive responses. [Ref **physicsgym**] The sports most commonly used for instruction are traditionally male, and could leave female students feeling overlooked. Enter, roller derby: the up and coming, fast paced, hard hitting, all women sport. Roller derby is often touted as being one of the fastest growing sports in America. It is new, fresh and exciting; and it's **full** of physics!

Angell et al (2004) found that students, especially female students, consider physics to be one of the most difficult subjects. The study also proclaims that physics students find developing a sound understanding of physics concepts to be both essential and difficult. [Ref **physicsfrightful**] The perceived complexity of physics topics by students is a good reason for physics educators to strive to showcase physics principles in new and interesting situations that can increase engagement for all students.

Literary Review

Modern Roller derby is a relatively new sport which reentered the public sports scene in 2001. As a result there are very few papers written on the topic. Most peer reviewed papers that mention roller derby focus on women and social structure. For these reasons, many articles I have referenced are about other sports which share certain similarities with roller derby.

Perhaps the most pertinent article found while researching this topic is *Physics on Rollerblades*, by Eugenia Etkina [Ref **Etkina98**]. Etkina used rollerblades to introduce basic kinematics to her students and then used that foundation to expand their knowledge into the more complicated areas of curvilinear and circular motion, inertia and centripetal force. Student interviews allowed her to record the positive effects the rollerblading activity had on her students. After Etkina's rollerblading unit her students were able to "see physics everywhere."

Snowboarding is a sport where the athletes can fall from high which makes understanding the mechanics of falling is important to snowboarders. Falling is very common in roller derby, so falling safely is essetial. Michael O'Shea explores the physics of several different types of snowboard drops in his article, *Snowboard Jumping, Newton's Second Law and the Force of Landing*. [Ref **snowboard**] O'Shea shows how physics can be used to find the force a snowboarder must endure when hitting the ground. The distance the snowboarder bends his/her legs and how soft or packed the snow is has an impact on the force felt by the snowboarder. In roller derby there are several different ways to fall properly which will be explored in this paper.

Brenda "Skater Bater" Delano wrote a short and concise article for *American Fitness* explaining the basics of roller derby. A first time fan will most likely find roller derby very confusing, but with Delano's breakdown of the sport, any fan can get up to speed in just a few minutes. Delano describes the basic rules and game-play of the sport, as well as the intense effort skaters must put forth in training. [Ref **derbybasics**]

For a more in depth view of roller derby, there are two very helpful books available. *Roller Girl*, by Melissa "Melicious" Joulwan [Ref **rollergirl**] and *Down and Derby*, by Jennifer "Kasey Bomber" Barbee and Alex "Axles of Evil" Cohen [Ref **downderby**] contain a wealth of information about roller derby and its roots. Both books provide information on how derby started, failed and came back (several times) along with the basics of the game and even player profiles and interviews. Both books provide the same facts but with a different flair that really paint a full picture of the world and history of roller derby.

A Brief Introduction to Roller Derby

"It's like Wayne Gretzky said: "Skate to where the puck is headed, not to where it's been"...except of course, in our case the "puck" is the opposing jammer, or a blocker we're trying to control...and it has a mind of its own. Roller derby is so much better than hockey."
Resident Eva (Roc City Roller Derby)

Many people I have talked to recently are unaware of the recent resurgence of roller derby, yet people do seem to remember roller derby's initial incarnation. With banked tracks, high speeds, minimal safety equipment and skaters with strong personae it is difficult to forget the roller derby created and promoted by Leo Seltzer in the 1930s. [Ref **downderby**] The 1970s the gas crisis and the increased theatrical nature of the roller derby caused the sport's popularity to wane. Fortunately, in 2001 a group of people in Texas gathered to begin roller derby's meteoric comeback. [Ref **rollergirl**]

These days the most common form of roller derby is played on a flat track and is regulated by the Women's Flat Track Derby Association (WFTDA.) Two thirty minute ha;ves are devided into an indeterminate number of "jams" which can last up to two minutes each. At the start of each jam eight blockers, four from each team, line up together forming "the pack." [Ref **wftdarules**]One jammer from each team starts behind the pack and earn one point for each opposing skater they pass legally and inbounds. [Ref **derbybasics**] Throughout the jam. the blockers are positioning themselves to help their jammer and stop the opposing team's jammer with a variety of hits, blocks and assists. After the jam ends, the skaters leave the track and each team has 30 seconds to get a fresh lineup of skaters out for the next jam. [Ref **wftadarules**]

Experimental Equipment

Attempting to write sample physics problems for roller derby caused me to wonder things like, “How fast do we skate?” The lack of public knowledge concerning typical measurements for derby phenomena forced me to conduct some experiments of my own.

A basic method to calculate the speed of a skater was to time her laps and measure the distance of the path she followed. Then, using that information I was able to do some quick calculations to find her speed.

The Hot Wheels Radar Gun is a more technologically advanced ways I used to find the speed of a skater. It would be difficult to use a radar gun as a spectator at a bout. However, as a member of Roc City Roller Derby, I was able to use the equipment at practices and before bouts. Contacting the local roller derby league to ask permission to come to a practice or before a bout is an option for a student who wants to use this equipment for their own scientific exploration. Or, if possible, use the equipment with students who know how to skate so they may find their own speed on skates.

The Hot Wheels Radar Gun retails for $69.99 and requires four AAA batteries. The toy can be used to judge the speed of both Hot Wheels cars and bicycles and other real size objects, there is an option of full scale or 1/64 scale. The 1/64 scale is for finding the speed of a Hot Wheels car, and for all other applications the gun needs to be switched to full scale mode. The gun can display the speed in miles per hour or kilometers per hour. Students should be made aware that even though the gun is displaying a speed in kilometers, students still need to do a little math to get the m/sec unit desired for physics calculations.

I positioned myself at several different places around the track to try and get a good reading of the skaters as they skated past. I found I got the best readings at the end of the straigtaways. It also worked best when I pointed the radar gun at the skater's chest. I didn't try using the gun from the inside of the track because I didn't think I would get a good enough angle on the incoming skater. Since radar guns make use of the Doppler effect and reflected radio waves to find the speed of a moving object, being in the object’s direct path would yield the most accurate data. [Cite radar gun site] Using the radar gun when only one skater was passing at a time allowed me to be certain about which skater's speed the radar gun was displaying. I asked a few skaters to skate around the track as fast as they could and recorded an average of 10 - 12 MPH depending on the skater.

Kinematics of Roller Skating - Roller Derby Style

In roller derby, skaters are always accelerating or decelerating. Skaters generally accelerate by pushing off of the floor with their skates. Skaters use a combination of crossovers and sculling to gain and maintain speed. Crossovers are when the skater picks up her outside foot to step over the inside foot to push herself toward the center of the track. Sculling is when the skater keeps all eight wheels on the track and uses a sideways pushing motion to propel herself forward.

Using both the stopwatch and the radar gunI was able to find the speed while sculling and crossing over.

Stopwatch

The following chart shows the data I collected with my stopwatch while RCRD skater, TaTa Pain, raced around the track. When using crossovers, TaTa followed a circular path and when she was sculling she followed the inside line of the track.

	crossovers	**sculling**
	Δt	**Δt**
lap 1	13 seconds	12 seconds
lap 2	10 seconds	12 seconds
lap 3	9 seconds	10 seconds
average	10.6 seconds	11.3 seconds

The data lets us compare the two styles of skating. At first glance, the similarity in the times for each lap could lead one to believe that there is little difference between the two skating styles. However, TaTa folllowed two different paths when using these two different skating styles. In the first trial, using constant crossovers, she was following a circular path as she skated on the inside line at the turns and toward the outside line on the straight aways. In the second trial, TaTa was hugging the inside line as she sculled around the track.

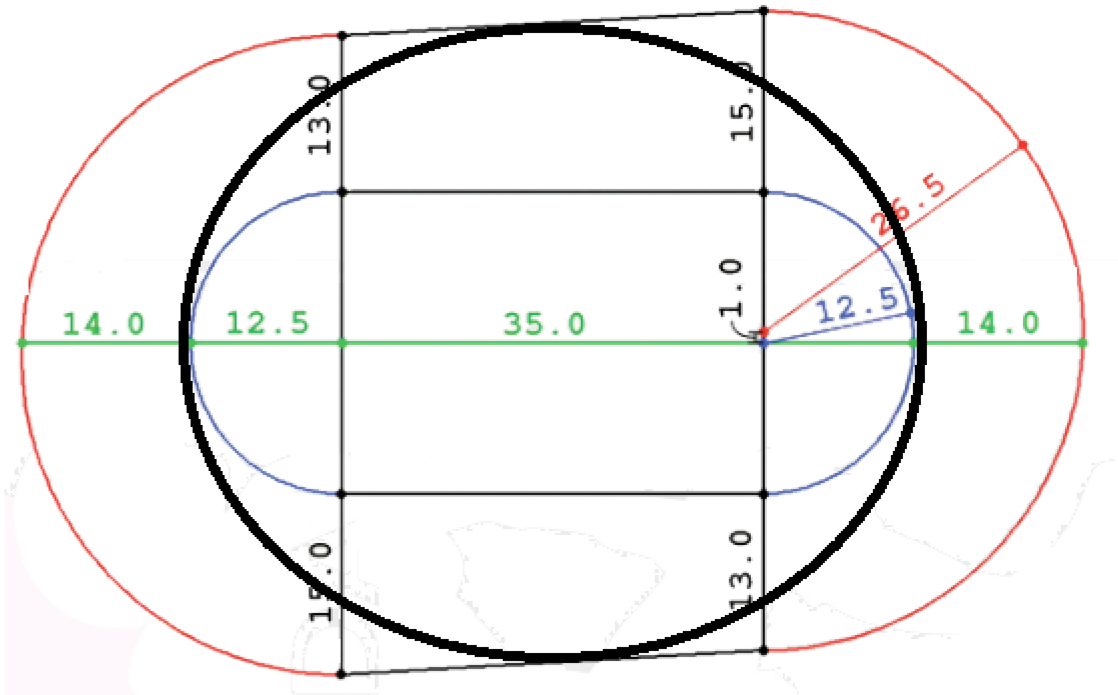

Image info: This figure shows the dimensions of the WFDTA regulation track. I drew the thick black line to show the path followed by TaTa as she skated with crossovers. The inside line of the track is shown in blue on the turns and black on the straightaways. (©WFTDA)

According to WFTDA, the circumference of the inside line measures 148.5 On the other hand, the circular crossover path is 178 ft. Since the crossover path is longer, students might expect it to take more time to traverse in comparison with sculling along the shorter path on the inside line. Knowing the difference between the two paths TaTa skated and the difference between the two methods employed will help students to compare the similarities in the times recorded for each lap. Asking a student to develop a robust explaination as to why the times are so similar is a great opportunity for students to demonstrate a firm understanding of the relationship between time, distance and speed.

To clarify the relationship between speed, distance and time using the two skating styles, students can calculate the speed of the skater as follows.

Finding the average speed of a skater sculling along the inside line:
Distance = 148.5 feet or 45.3 m
Average lap time = 11.3 seconds

Velocity = Distance / Time = 45.3 m / 11.3 s = 4 m/s or 8.9 mph

Finding the average speed of a skater following an elliptical path skating with all crossovers:
Distance = 178 feet or 54.3 m
Average lap time = 10.6 seconds
Velocity = Distance / Time = 54.3 m / 10.6 s = 5.1 m/s or 11.4 mph

When following the shorter path and sculling, Tata's average speed was slower than when she was using crossovers and following a longer path.

Hot Wheels Radar Gun
Using the Hot Wheels Radar Gun, I found TaTa's average speed to be between 10 and 12 MPH at the end of a straightaway. Slower speeds were recorded while TaTa was sculling and the faster speeds were seen when she was using primarily crossovers.

Unintentional Deceleration and Intentional Deceleration
Or
Falling and Stopping

Falling and the trajectory of objects in circular motion

Falling is something a spectator will see a great deal of at a derby bout and those observations provide a perfect opportunity to demonstrate the difference between angular acceleration and angular velocity. A fallen skater is no longer accelerating towards the center of the track she will slide to the edge, or perhaps even off the track. This is because her angular acceleration is now zero so she will no longer have any force pushing her towards the center of the track. Since the direction of angular velocity is tangential to the circular path the skater is traveling on, students can predict which spectator will get a flying derby girl in their lap after a fall and slide into the crowd.

The photo above shows a fallen skater sliding off the track. The skater in red is at the mercy of her own inertia as she slides away from the track. However, the skater in blue, Wolf Blitzkreig, is still on her skates and can shift her center of mass to maintain enough angular acceleration to keep her position on the track. This is very similar to the traditional demonstration of whipping a string with a ball at the end around your head and cutting the string to watch the ball fly off away from your hand. In the roller derby example the ball is the red skater and the string can be represented by the vector of centripetal acceleration caused by skating. Once a sksater is no longer up and skating she flies off in the direction of her velocity just prior to her fall.

This could be a good place to ask to compare the trajectories of the skater's slide after a fall when she falls on the curved portion of the track versus the straight portion of the track.

Falling and sliding to a stop

Studying falls and stops in roller derby provides a good example of friction bringing an object in motion to a halt. By recording the stopping time and stopping distance we can compare the magnitude of deceleration for various falls and also intentional stops.

Another one of my teammates from Roc City Roller Derby, Shockin' Audrey, demonstrated two controlled falls while I recorded her stopping distance and time. I used a stopwatch to record the time it took her to come to a complete stop after she hit the floor. The skate floor was constructed of one by one foot plastic tiles. I counted these tiles to find an approximate stopping distance once Shockin' had come to a complete stop.

1. The One Knee Fall

Insert stick figure image of one knee fall (sans force vectors)

	time (seconds)	distance (feet/meters)
Trial 1	2.72	23.5 / 7.2
Trial 2	2.52	24 / 7.3
Trial 3	2.79	28.5 / 8.7
Average	2.6	25.3 / 7.7

1. Two Knee Fall, "Rock Star"

insert stick figure of rockstar (sans force vectors)

	time (seconds)	distance (feet/meters)
Trial 1	1.67	14 / 4.3
Trial 2	1.53	13 / 4

Trial 3	1.46	14 / 4.3
Average	1.6	13.7 / 4.2

The data in these charts provides teachers with appropriate values to formulate physics examples related to roller derby. Finding the initial velocity the skater was moving at just before she began her deceleration due to the fall is one example of a physics problem to solve.

Sample example:
While coasting to rest in a two knee fall, it took Shockin' Audrey 1.6 seconds to travel 4.2 meters. What was her velocity just before she before she fell?

Using the kinematics equation below is a good way to answer this problem:

$$d = \frac{v_i + v_f}{2}t$$

Known:

$v_f = 0$

$t = 1.6\ s$

$d = 4.2\ m$

yields:

$v_i = 5.3\ m/s$

Using what they've learned, students can use physics to delve into the difference between the stopping time and distance for both answers.

Stopping Intentionally

Skaters have numerous methods for stopping at their disposal. I recorded the stopping times and distance for several of these methods .

1. The Toe Stop

The science of the toe stop could be a paper all on its own. The variables that could be included in an extensive study of toe stops are many. Toe stops are made from many different materials, and in different shapes. Sin City Skates, a popular site for buying roller derby equipment, sells fourteen different types of toe stops. The length of the toe stop can be short and close to the skate, or long and near the floor. The toe stop rubs away every time it is used; this wear and tear changes the toe stop and also affects stopping ability. Finally, the skater's technique also influences the effectiveness of stopping.

The basic method of stopping using a toe stop is to extend one skate behind the other, dragging the toe stop on the ground. The harder the skater pushes the toe stop into the ground, the quicker she will slow down.

Shockin' Audrey performed three controlled toe stops. I recorded her stopping distance and time just as I did with the one and two knee falls.

	time (seconds)	distance (feet/meters)
Trial 1	3.63	31/9.45
Trial 2	3.70	32/9.45
Trial 3	3.98	32/9.75
Average	3.77	31.67/9.65

A cursory glance of the above table in comparison to the data tables for the one and two knee falls gives students and teachers the valid impression that using a toe stop to come to a complete stop uses both more time and distance than a simple fall. To add a numerical value to the conceptual explanation of this stopping method, the student would need to find the rate of deceleration and the skater's initial velocity.

Known:
$v_f = 0\ m/s$
$d = 9.65\ m$
$t = 3.77\ s$
Equations:
$d = \frac{v_i + v_f}{2} t$
$d = v_i t + \frac{1}{2} a t^2$
Yields:
$v_i = 5.1\ m/s$
$a = 1.53\ m/s^2$

2. The T-Stop

The t-stop is common method for stopping in crowded areas since it allows the skater to keep her legs close together. To execute this stop, the skater must place one of her skates perpendicular to the rolling skate. The stopping power from the t-stop comes from the skater pushing the wheels of the perpendicular skate down on the ground.

Shockin' Audrey performed three controlled T-stops and I recorded her stopping distance and time.

	time (seconds)	distance (feet/meters)
Trial 1	2.51	18/5.49
Trial 2	2.41	22/6.71
Trial 3	2.51	18/5.49
Average	2.48	19.33/5.89

The T-stop brings the skater to a stop about one second faster and in almost half the distance when compared to using the toe-stop. Since roller derby is a game where speeding up and slowing down happens constantly, having an effective method of stopping quickly is crucial for serious skaters.

As with the toe stop, there is an interesting materials aspect to the T-stop that can have a significant impact on the skater's ability to stop. A quick glance back at Sin City Skates' website shows more than forty different types of wheels available for sale. If one were to peruse other skate-shop sites they would discover even more types of wheels. Here too, the condition of the wheels is important to note.

3. The Plow Stop

The plow stop is more than just a method of stopping. It is also a method for positionally blocking other skaters. To execute a plow stop the skater must skate with a wide, low stance, bending at her knees. She pushes the innermost wheels of each skate into the floor while turning her toes in. This causes her to slow down quickly and,depending on her stance, can also act as a barrier on the track, impeding skaters who hope to glide past her.

I chose to collect data on two skaters to display the differences in using the stop with vaying levels of success. So this time I, Farrah Daze Rage, joined Shockin' Audrey on the track with my skates on and both of our stopping times and distances were recorded.

	Audrey time (seconds)	Audrey distance (feet/meters)	Rage time (seconds)	Rage distance (feet/meters)
Trial 1	3.07	27/8.23	1.46	14/4.27
Trial 2	2.79	26/7.92	1.81	16.5/5.03
Trial 3	2.76	22/6.71	1.60	15/4.57
Average	2.87	25/7.62	1.62	15.17/4.62

The difference in effective use of the plow stop can be seen in the differences between Audrey and Rage's average stopping time and distance. Each skater has her preferred stopping method, and it is usually the one she is most proficient at.

4. The Tomahawk

The tomahawk is one of the most immediate ways to come to a controlled stop while on skates. In contrast to the plow stop, the tomahawk does not require the skater to spread out on the track, so this stop can be executed in tight packs without fear of tripping other skaters. The tomahawk is also one of the most difficult stops for a skater to learn.

To do a tomahawk stop the skater must first transition from skating forward to skating backwards. The skater will lean forward, in the direction opposite to her direction of motion, with her weight on her toes. Then she lifts up off her heels and rear wheels to her toe stops. Without any wheels rolling and only two toe stops dragging under her, the skater skids to a stop very quickly.

Shockin' Audrey performed three controlled tomahawks and I recorded her stopping distance and time.

	time (seconds)	distance (feet/meters)
Trial 1	.97	9/2.74
Trial 2	1.32	11/3.35
Trial 3	1.18	9/2.74
Average	1.16	9.67/2.95

The tomahawk is the fastest way to stop when compared to the other methods discussed in this paper. Once a student has been exposed to roller derby they can use physics to explore the differences between the numerous ways derby skaters stop on the track.

Conclusion

Using practical examples such as sports to help teach physics helps students to better grasp the new and complex concepts that are part of the Regents physics curriculum. Including roller derby scenarios with today's commonly used sports scenarios to teach physics can add something new and unique and also engage more female students due to female dominance in the sport of roller derby.

My goal with this paper was to introduce roller derby to the physics teaching community and provide ideas for physics questions and a basis for numerical values to use in those questions to keep the scenarios valid. I also hope I was able to show that there is more the roller derby than just kinematics; materials science is one of many other areas that could also be explored if students showed interest.

Engaging students is important, and helping students develop an authentic understanding of the physical world should be our goal. With more scenarios for practice questions we increase the chance that more students will see physics everywhere.

References

How Radar Guns Work. (2005-2012). Retrieved Devember 12, 2011 from Radar Guns Web site: http://www.radarguns.com/how-radar-guns-work.html

Etkina, E. (1998, January). Physics on Rollerblades. *The Physics Teacher*. 26, 32-35.

Hatch, G. & Smith, D. (2004, January). Integrating Physical Education, Math, and Physics. *Journal of Physical Education, Recreation and Dance, 75,* 42-50.

Angell, C & Guttersrud, O & Henriksen, E. (2004, September). Physics: Frightful, but Fun. Pupils' and Teachers' Views of Physics and Physics Teaching. *Science Education, 88,* 683-706.

Haché, A. (2008, October). A Cool Sport Full of Physics. *Physics Teacher, 46,* 398-402.

O'Shea, M. (2004, July). Snowboard Jumping, Newton's Second Law and the Force on Landing. *Physics Education, 39,* 335-341.

Van Patten, J & Chao, C & Reigeluth, C. (1986). A Review of Strategies for Sequencing and Synthesizing Instruction. *Review of Educational Research, 56,* 437-471.

Joulwan, M. (2007). *Roller Girl (1st ed.).* New York, NY: Touchstone.

Delano, B. (2010 September/October). Roller Derby. *American Fitness, 28*, 45-45

Rules Central-Woman's Flat Track Derby Association. (2009-2012). Retrieved December, 12, 2011 from Women's Flat Track Derby Association Web site: http://wftda.com/rules

Appendix B: WFTDA Track Design and Specifications. (2005). Retrieved December 12, 2011 from Women's Flat Track Derby Association Web site: http://wftda.com/rules/wftda-rules-appendix-b-track-design.pdf

Barbee, J & Cohen, A. (20). *Down and Derby*. (1st ed.).

(Geissler, E. M. (1998). *Pocket guide to cultural assessment* (2nd ed.). St. Louis, MO: Mosby.)