Angela Chen
21M.735
12/10/05
Final Project

Zero-Throw Casters

I. Introduction

Moving three-dimensional scenery on a stage is made easier and faster through the use of casters. There are two general types of casters: swivel and fixed.

Swivel casters are used in applications where the scenery needs to be able to move freely in any direction. Scenery, when not in use, is usually stored off to the side of the stage. When it is ready to be used, often the path which it must travel to get onto the stage is not a straight one. Therefore, it must use swivel casters which will adapt to what ever direction it needs to travel. Swivel casters are commonly seen on the bottoms of dollies, carts, strollers, and any object that is made to be pushed around an unspecified path.

Fixed casters, on the other hand, are used in applications where the scenery needs to move in one direction only. For example, fixed casters can often be seen in turntable construction. Turntables require a repeatable rotation about a single pivot point. This can be achieved by mounting several fixed casters radially from a common pivot point. Fixed casters can also be mounted parallel to each other to produce a repeatable straight line path.

Sometimes, Fixed and swivel casters can be combined too. For example, a cart can have two swivel casters in the front and two fixed casters in the rear. The fixed casters keep the cart moving in a relatively straight path when it is being pushed down an aisle. The swivel casters allow for the cart to turn corners once the end of the aisle has been reached. If the cart is turning

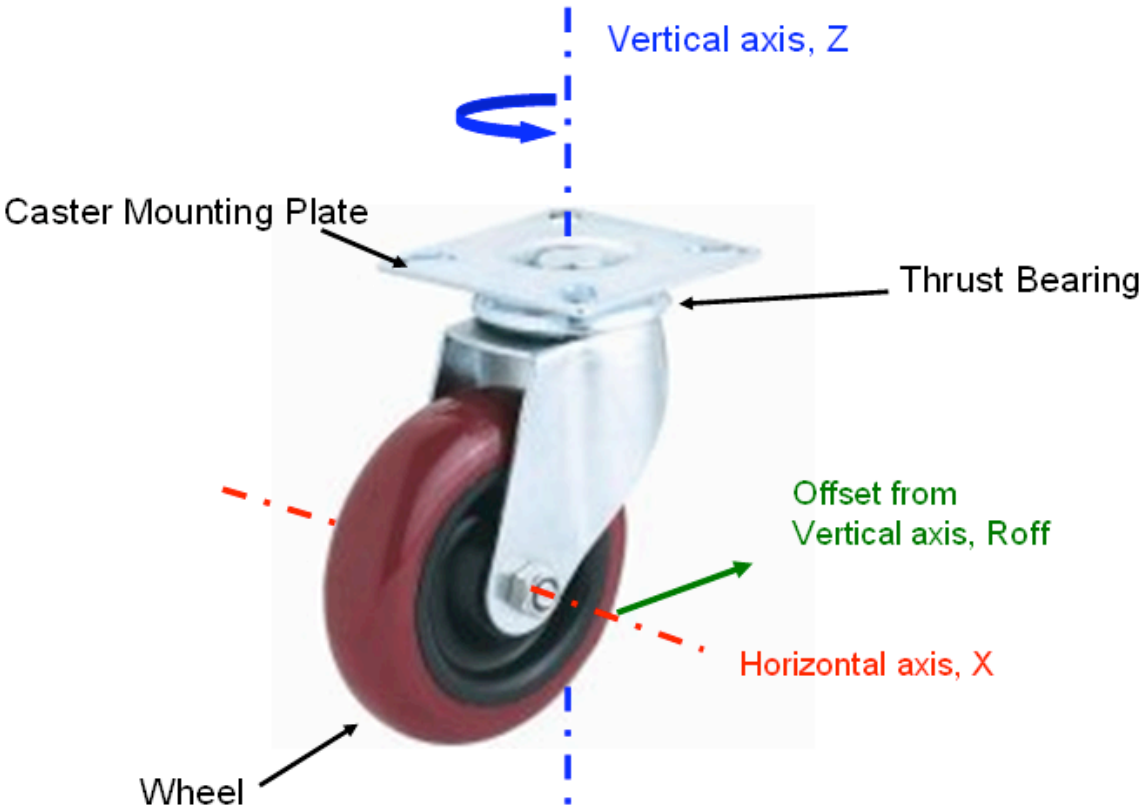
right, the cart pivots around the rear right caster and the rear left rotates radially around that point.

Fixed and swivel casters are the most common methods used in scenery transportation, but they both have their limitations. Fixed casters, although they allow for smooth repeatable motions once the scenery is set on stage, there is always the problem of actually getting the piece of scenery on and off stage. Swivel casters, on the other hand, allow for easy transport on and off stage. However, any change in the direction of motion causes the casters to pivot around their point of contact with the floor and creates an undesirable lurch, or throw. Therefore, any manipulation of the scenery on stage, especially when reversing direction is usually not very smooth or attractive.

The solution to universal motion of a platform without the throw imposed by the standard swivel caster is the use of zero-throw casters. The design of the zero-throw caster allows for the free motion that swivel casters have, but it also eliminates the unwelcome lurch when changing directions. The basic components of zero-throw casters include three swivel bearings mounted to a caster plate. The caster plate is attached to the platform via a thrust bearing and mouting plate. This allows the caster plate to rotate independently of the platform.

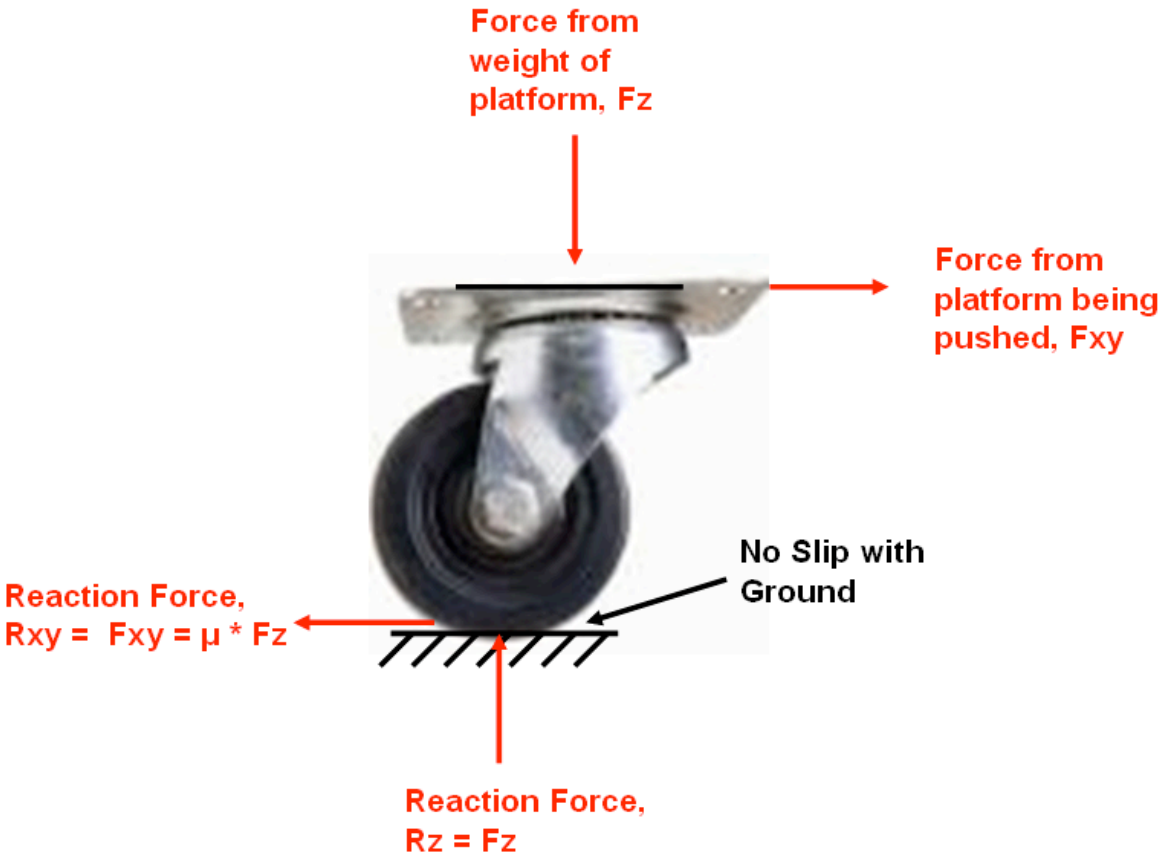
Angela Chen
21M.735
12/10/05
Final Project

II. The Physics of Zero-Throw Casters



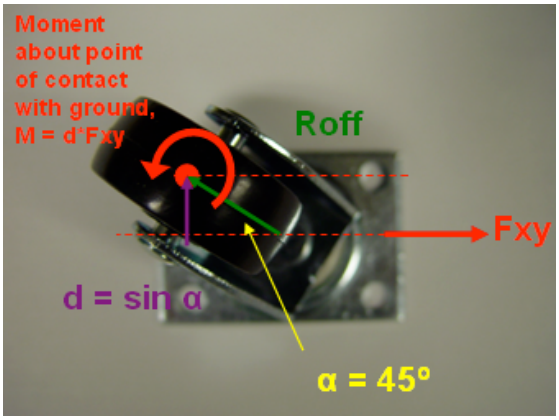
To understand how a zero-throw caster works, one must look at the physics behind swivel casters first. Looking closely at the components of a swivel caster, it is made up of a wheel that is free to spin around a horizontal axis. The center of the wheel is offset from and allowed to rotate around the center of the mounting plate via a thrust bearing. The key to how a swivel caster works is the fact that wheel is offset from the mounting plate. It is easy to understand if one looks at a free body diagram of a swivel caster as it is supporting a load and is being pushed in a certain direction.

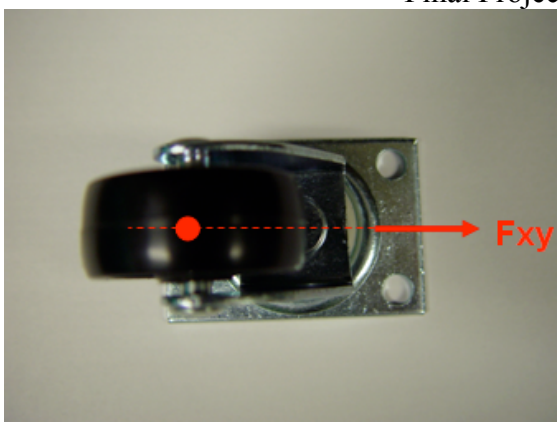
Angela Chen
21M.735
12/10/05
Final Project



Assume no slip between the wheel and the ground. The only points where external forces act are on the mounting plate and at the point of contact where the wheel contacts the rolling surface. Therefore, vertical forces and horizontal forces that act at these two points should balance. Also, since the wheel and mounting plate are connected via a thrust bearing, there should be no moment exerted about the central pivot.

Angela Chen
21M.735
12/10/05
Final Project



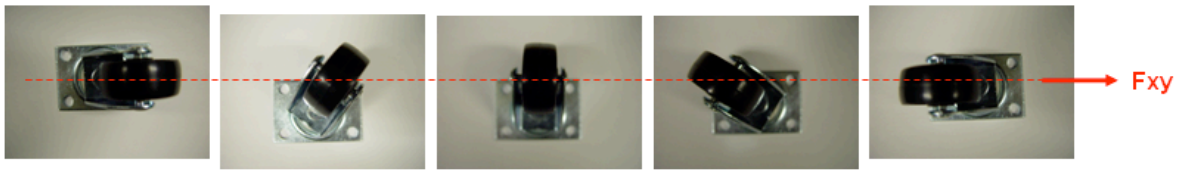


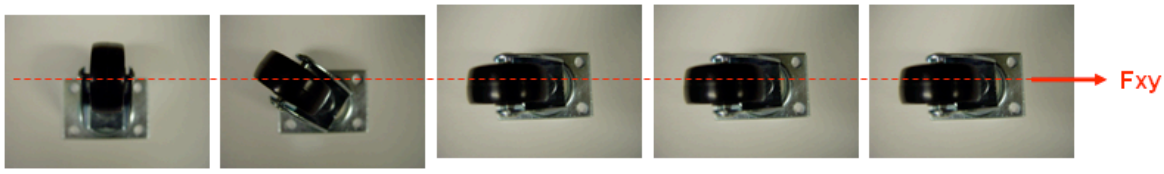
As one can see, if the wheel is not in line with the direction of motion, the force exerted at the point of contact with the rolling surface is offset from the force exerted at the center point of the mounting plate resulting in a moment arm. The moment arm depends on the angle of tilt of the wheel, with the maximum being at the distance of the wheel/mounting plate offset. However, since no moment can be exerted about the central pivot, the wheel will rotate to eliminate the moment arm. Therefore, it will self align itself to the direct of motion of the platform.

There are two configurations that the swivel casters can take on to align its wheels with the direction of motion. In one configuration the wheel lags the mounting plate a little, and in the other, the wheel leads. The difference between these two configurations is stability. The lagging configuration is a lot more stable. Under any small perturbations, the wheel will always choose to return to this configuration. When the wheel is in the leading configuration, small deviations in the angle of the wheel will work only to magnify the moment arm initially and then eventually eliminating it as the wheel takes on the lagging configuration. This instable configuration is what causes the unwelcome lurch, or throw when transporting platforms with swivel casters.

Angela Chen
21M.735
12/10/05
Final Project

Unstable Leading Configuration



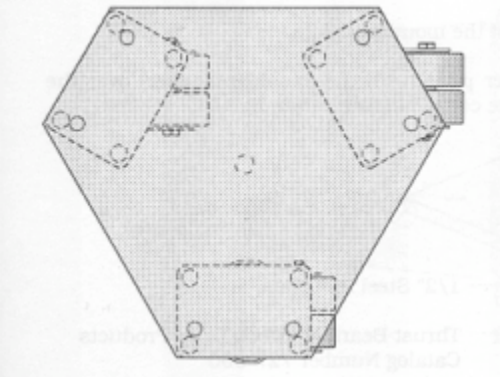


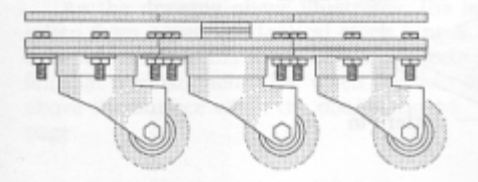
Stable Lagging Configuration

The caster mounting plate has to rotate around the wheel/ground contact point so that is in the lagging configuration. The wheel cannot rotate around the caster mounting plate because there is no slip between the wheel and ground.

Now in the case of zero-throw casters, there are three swivel casters. There is nothing special about the number three. Using 2 or 8 casters would accomplish the same objective, however, zero-throw casters with only two casters would not be able to stand on their own, and 8 casters would be excessive because 3 is the minimum number of contact points needed to define a plane. The three swivel casters are then isolated from the platform via a thrust bearing between the caster plate and platform mounting plate. As the platform is moved, some swivel casters maybe in the leading or lagging configurations. Leading swivel casters force the caster mounting plate to move around the wheel. The caster plate rotates to balance out the throw of the casters, but it has no effect on the platform since the caster plate has been isolated from the platform.

Angela Chen
21M.735
12/10/05
Final Project





III. Fabrication of Zero-Throw Casters

Zero-throw casters are not commonly found and sold in stores. And if they are, they are usually expensive. Therefore, it is beneficial to understand how to design and build relatively inexpensive zero-throw casters. When designing zero-throw casters, several design issues need to be taken into consideration. Some of these issues include:

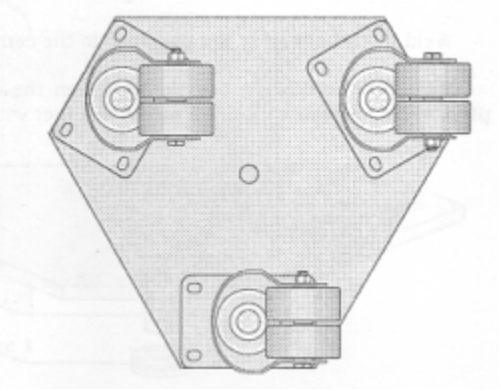
1. Spacing of casters
2. Size and shape of caster plate and platform mounting plate
3. Load rating of the central pivot of the caster plate and of the casters

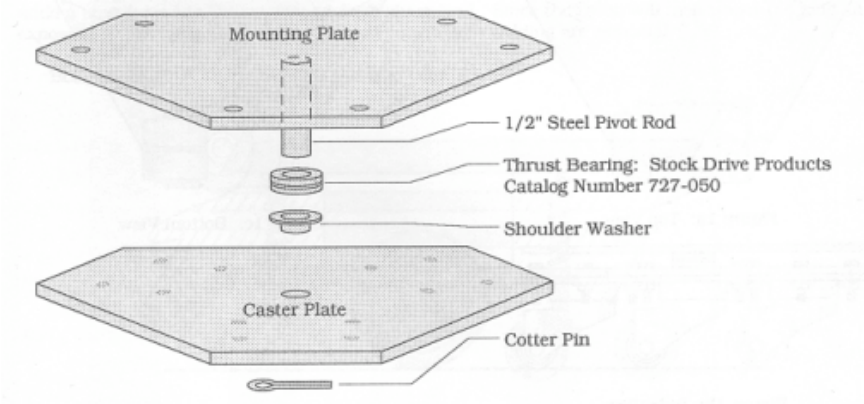
The spacing of casters is important because there is a minimum and maximum spacing depending on the application. There is a minimum because casters have to be spaced far enough apart to avoid colliding into each other as they rotate. The wider the spacing of the casters, the more easily they will turn. The spacing of casters determines the size of the caster plate. There is also a maximum spacing because bending of the caster plate can be a problem if the caster plate is too large. The shape of the caster plate and platform mounting plate should be chosen so that one can have easy access mounting holes when attaching the casters to the caster plate or when attaching the mounting plate to the platform. To determine the minimum number of zero-

throw casters that are needed to support a given load, one should check the load ratings of the thrust bearings between the caster plate and platform mounting plate. The load ratings of the casters multiplied by the number casters should also be confirmed to be greater than the load being supported.

TWO METHODS OF FABRICATING ZERO-THROW CASTERS

METHOD 1: Taken from James Bender in the Technical Brief from the Yale School of Drama





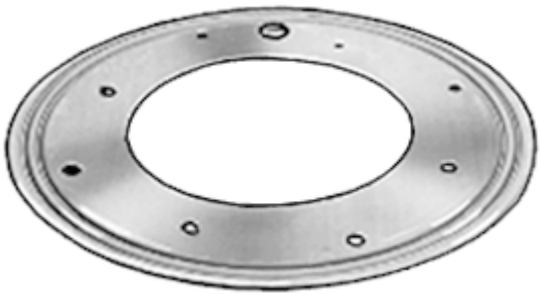
1. Cut a _″ steel caster plate ($124.38 for 2 square feet) in the shape of an equilateral triangle with the vertices cut off.
2. Drill holes (at least 5/16″diameter) in the mounting plate for attachment to the platform.
3. Drill 12 holes in the caster plate for mounting the casters ($25 for 3) as well as a hole in the center to receive a shoulder washer in the caster plate's central hole.
4. Attach the casters to the caster plate and insert the shoulder washer ($2.80 each) in the caster plate's central hole.

5. Cut a _″ pivot rod to a length of 2″ ($4.95 for 2”) and drill a hole through one end to receive a cotter pin which will be 1/8″ below the caster plate when the whole unit is together.
6. Weld the other end of the pivot rod to the mounting plate.
7. Slide first the thrust bearing ($3.27 for one) and then the caster plate (with the shoulder washer) over the pivot rod, and secure all three pieces together with the cotter pin ($0.71 each).
8. Total Price → ~ $160 plus price of fasteners
9. Machining Required : Milling, Lathing, Welding, Drilling

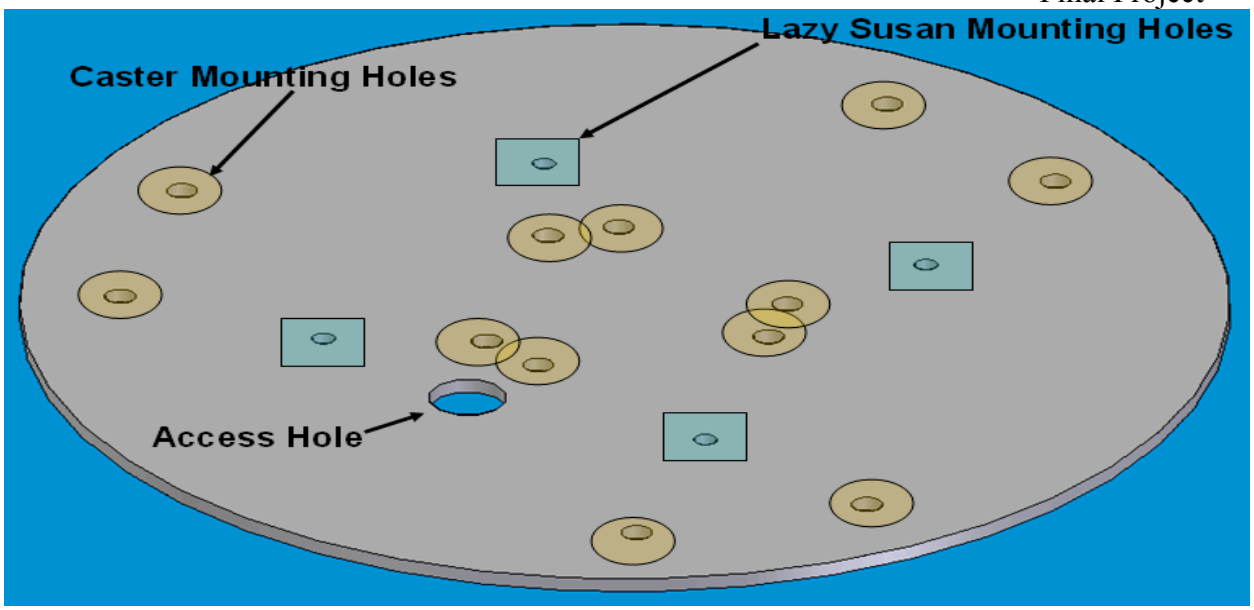
METHOD 2:

1. Cut a disc of 3/4″ plywood (free if using scrap)large enough to allow all three caster spaced 120º around to rotate plus some extra room.
2. Attach casters ($25 for 3) to plywood caster plate.
3. Center a lazy susan bearing ($5.57 for 1) on other side of caster plate and attach it.

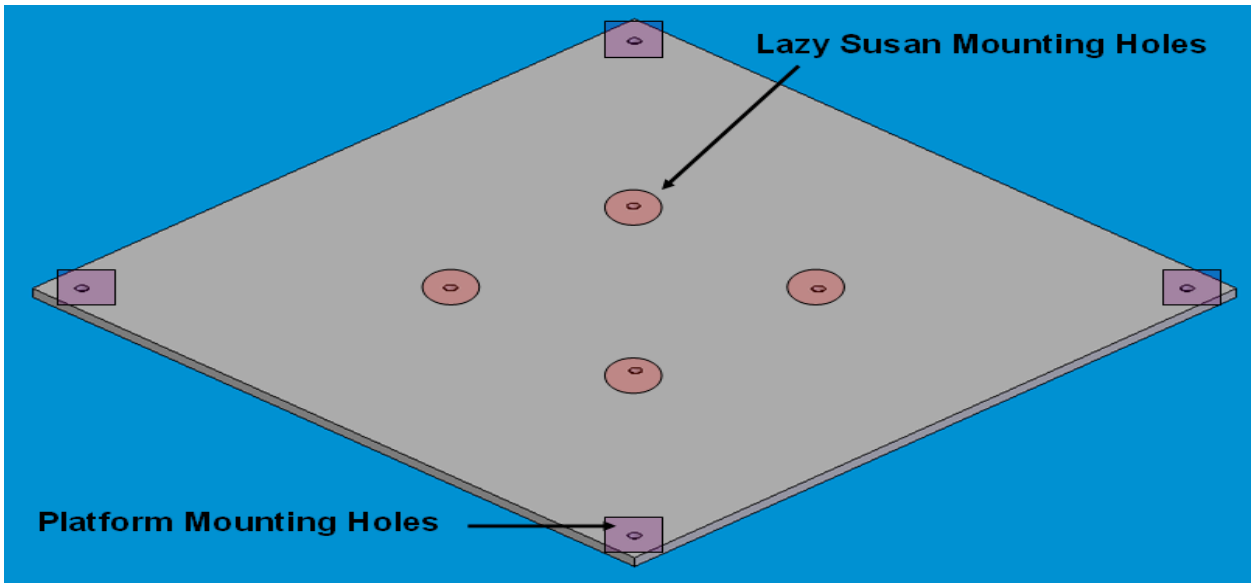
or



4. Drill an access hole through the caster plate so that you have access to the other side of the lazy susan bearing.

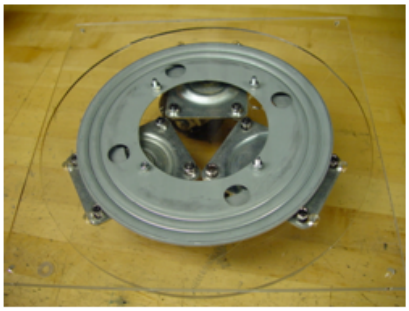
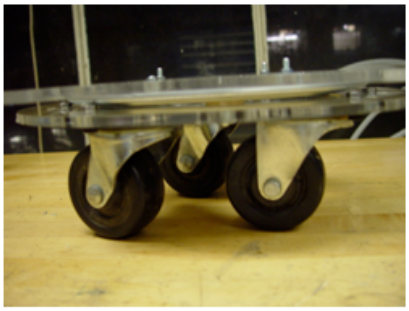
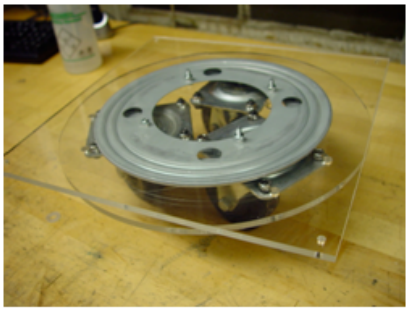


5. Attach the other side of the lazy susan to a square piece of plywood. This will act as the platform mounting plate.



6. Total Price → ~$30 plus fasteners
7. Machining Required : Bandsaw, Drilling

Angela Chen
21M.735
12/10/05
Final Project

IV. Conclusion

Zero-throw casters, although a little more complex than stock fixed and swivel casters, can be very useful in producing smooth motions on stage. Understanding the physics of a regular swivel caster allows one to understand how zero-throw casters work. The key is the decoupling of the casters from the platform they are transporting via thrust bearings. Zero-throw casters are rarely sold, and when they are, they are usually expensive. Therefore, it is very useful to know how to fabricate one's own set of zero-throw casters inexpensively. Two methods were presented. One required more machining but would last a lot longer. The other is a quick and cheaper to fabricate but is less robust. Zero-throw casters are lot more versatile and should be considered when deciding how to transport large pieces of scenery that have to follow a set path on stage.

Angela Chen
21M.735
12/10/05
Final Project

References

Bender, James. "Zero-Throw Casters." *The Technical Brief Collection: Ten Years of Solutions to Recurring Problems in Technical Theatre.* Vol 1-10. New Haven, CT, 1992: pg 193-4.

Mortimore, Curtis L. Technical Director at Ball State University, Dept. of Theatre and Dance. Also credited Phil Haslam, Stirling Shelton, and Chris Fretts.

Parker, W. Oren and R. Craig Wolf. *Scene Design and Stage Lighting* 7th ed. New York, 1996

http://www.amazon.com – for images

http://www.castercity.com/specific-app-casters/theatrical-casters.htm

http://www.centerlinestudios.com/caster.html

http://www.sdoperascenicstudios.com/about.html

https://sdp-si.com/eStore/Direct.asp?CP=Index.htm

http://stagecraft.theprices.net/digest/2005/10_October/StagecraftDigest-0542_Fri_2005-Oct-07.txt