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| PHYS1521  **Math and Physics for Games**  Realistic Projectile  Simulation Report  Digital Media and IT  School of Applied Sciences and Technology |

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| **Section:** | A01 |
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*Fig. 1.* Screenshot of Projectile Motion Flash Simulation.

From “Projectile Motion” by Splung.com at <http://www.splung.com/content/sid/2/page/projectiles>

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# Introduction

Projectiles are moving objects that have plenty of physics associated with them. Our project is to create a virtual and realistic simulation involving launching projectiles at several angles. We chose this topic because it is familiar to us due to our Math and Physics for Games class at NAIT. We also see this as an excellent opportunity to translate our calculations into visual results.

There are plenty of video games that use projectile-like assets. The physics behind these assets are a lot more complicated than they may seem at first. For example, the game “Angry Birds” uses birds as projectiles and they are affected by multiple forces. All these forces must be programmed in, otherwise the projectile may act differently than a user may expect. For example, a projectile may slow down faster than a user expected, hence ruining their attempt at the shot.

This report will highlight our efforts towards creating a realistic projectile simulation and will go into detail on how each physics concept involved affects the projectile.

# Concept

The simulation will involve two different scenarios. One scenario will have the projectile being launched from a cannon, and the other scenario having a ball being flung after multiple circular rotations around a center point. Our simulation will allow the user to change some of the variables in the simulation using a menu, this will demonstrate how well our mathematical calculations will react to the changes instead of being hard-coded values.

In our work, gravity’s acceleration will always be considered as -9.81 m/s2 as this is the constant we have been using in our physics class.

We’ll be using multiple concepts in our simulation. The concepts that we’ll be using that we’ve already learnt about in our Math and Physics for Games class include:

* Momentum Conservation between two colliding objects
* Linear Projectile Motion
* Rotational Projectile Motion

The following concepts are new to our group and will be the key points in our report. They will be explored in detail later:

* Drag Force/Air Resistance and Lift
* Torque

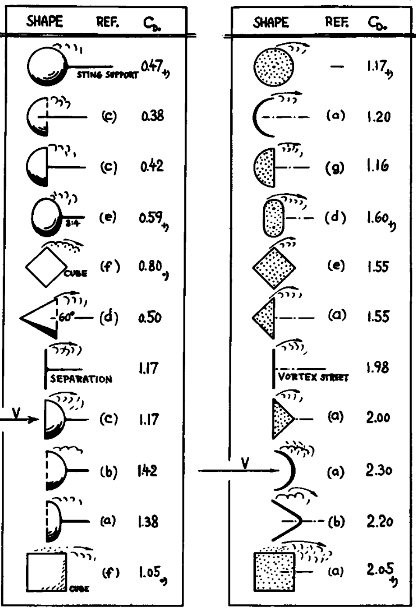
## Drag/Air Resistance and Lift

### What Is Drag / Air Resistance?

**Drag** (also known as **Air Resistance**) is a force that pushes in the opposite direction of an object’s velocity. Air resistance is dependent on an object’s velocity (Rit.edu, n.d.). So, the faster an object is moving, the more air resistance it will have. For example, a cube being dropped from a 500m high building will start with very little air resistance. However, as the object falls it starts to accelerate and the air resistance becomes a lot stronger.

Since air resistance is a force moving against our velocity, this means that the object’s speed will eventually hit a maximum value. The velocity of the object will no longer increase, and the air resistance will stay constant as well.

Drag is also dependent on the shape of the object being used. A sphere for example, will have less air resistance than a cube would. The reason for this is the **Drag Coefficient**.

The Drag Coefficient is a number that represents how much drag an object will have; it is dependent on the shape of the object being used. (engineeringtoolbox.com, n.d.). See Fig. 2 for a table full of drag coefficients and the shapes they are associated to.

Modern vehicles take drag coefficient into serious consideration, that’s why they have a very smooth and aerodynamic shape. Patrick E. George from HowStuffWorks.com gives the example of the Toyota Prius. He writes:

*“Among other efficient characteristics, its Cd of .26 helps it achieve very high mileage. In fact, reducing the Cd of a car by just 0.01 can result in a 0.2 miles per gallon (.09 kilometers per liter) increase in fuel economy.”*   
- Patrick E. George (March 2009)

To find the drag force, we must use the Drag Force formula (See Fig. 3.). The formula takes factors into account that we haven’t seen in class, such as **air density**, and the **frontal area** of the object.   
The density of the air that the object is travelling through is measured in kg/m3 (kilograms per cubic meter). It is calculated using the Air Density formula (See Fig. 4) However, as you may have seen from the figure, to find the density of the air we need to know the air pressure. Lucky for us, there’s another formula (See Fig. 5) to calculate this.

Fig. 2. Table of Drag Coefficients

From “Fluid-Dynamic Drag” by Sighard Hoerner (1965)

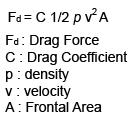
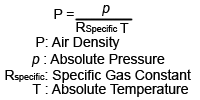
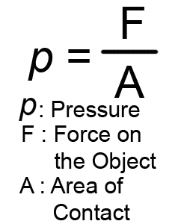


Fig. 3. Drag Force Formula

By Pierre G. (2017)

Fig. 4. Air Density Formula

By Pierre G. (2017)

### What Is Lift?

Fig. 5. Air Pressure Formula

By Pierre G. (2017)

### How Are These Relevant to Game Programming?

## Torque and Center of Gravity

### Torque

#### What Is Torque?

Torque is a force that causes an object to rotate. The amount it rotates is proportional to the torque applied and the object’s resistance to the rotation.

τ = Torque

I = the moment of Inertia

α = angular acceleration

To calculate torque

or ∅)

τ = Torque

F˔ = the perpendicular component of the force applied

F is the force applied

r = distance to the axis of rotation

∅ = the angle the force is applied

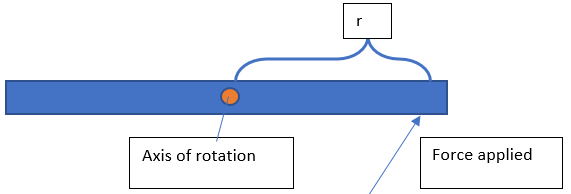
This looks like:

Fig. #-A. Application of torque

Alex Kinnear (2017)

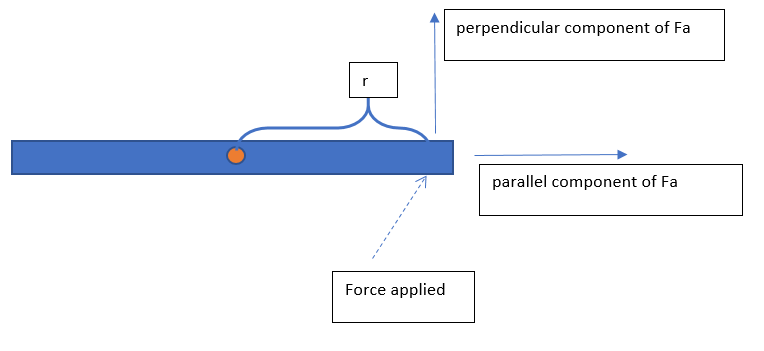
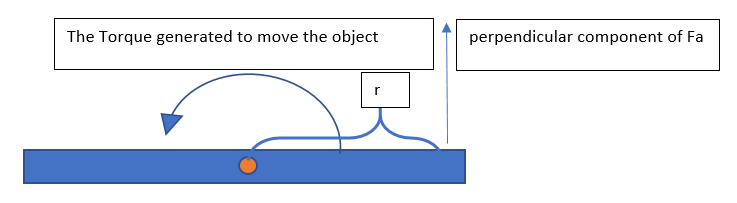


Fig. #-C. Application of Torque cont.

Alex Kinnear (2017)

Fig. #-B. Application of Torque cont.

Alex Kinnear (2017)

To calculate *I* calculus is needed however, there are many generic *I* ‘s available based on many common geometric shapes. So, it’s possible to find tables of equations for *I* in textbooks and other sources.

this will find the Inertia of a point object (mass is all at one point), add all point masses to get the sum. m = mass, r = distance to axis of rotation.

For an object that has its mass evenly distributed its moment of inertia can be…

where L is the length and the axis of rotation is at the end of the object. (rod)

where the axis is at the center. (rod)

where this is a cylinder with the axis through the center

for a sphere rotating with the axis through the center

And if you’re lazy and don’t want to learn calculus but still want to get its *I*, you might be able to find *I* by

Splitting the object into ‘common geometric shapes’, find the *I* from the center of one and have the rest as point masses.

Axis of rotation:

To find the axis of rotation determine if the object is fixed or free. If its fixed to something, that point would be the axis of rotation. If it’s free, it’s center of gravity would be the axis of rotation.

### Center of Gravity

#### What Is the Center of Gravity?

The center of gravity is the “center of weight” in any object, regardless of shape or size.

For primitive shapes, such as spheres, circles, squares and cubes which are symmetrical, the center of gravity will be the very center of the object because the mass is distributed evenly around it.

However, for more complex objects it would be necessary to determine the center of gravity (CoG) before being able to determine how it would react to Torque or another force. A good example of torque with “no fixed axis” is balance. Gravity works on the objects CoG as though it were the pivoting point and the rotates the object accordingly.

The easiest way to get the center of gravity is to create a reference point (X, Y or X, Y and Z coordinate graph) and put the object onto the reference.

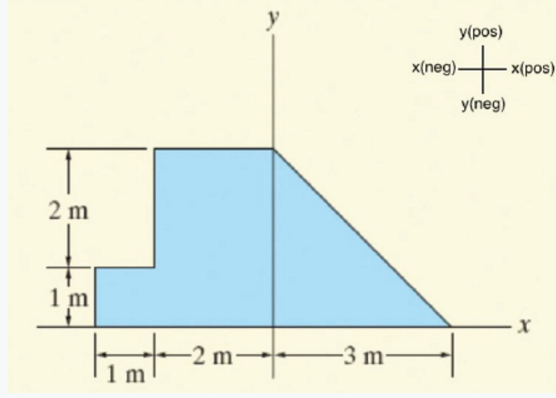


Fig. #-A. Calculating the Center of Gravity

From “How to Determine the Center of Gravity of Any Load” by Laura Hatton

Like so.

as long as the object is made of the same materials you don’t need to worry about what materials or mass make up the object as all of it would wind up having the same effect on the object’s CoG.

Once you have your reference and object, ‘split’ the object into primitive shapes then find and collect each of their CoG,

if the object has holes or sections of ‘nothingness’ you can treat them as being part of the primitive shape on the condition that you create a shape for them and find its CoG for those holes and note them as being “Void space” (for subtracting their effect later).

This would be an example of splitting the object into smaller shapes, it also has object 3 as the “void space”.

Fig. #-B. Calculating the Center of Gravity

From “How to Determine the Center of Gravity of Any Load” by Laura Hatton

The things to collect for each ‘object’ is the coordinate of its center of gravity and how much ‘weight’ it has (space it takes up, therefore area for 2D objects and Volume for 3D objects).

What to do with it:

D is the coordinate (X, Y and X) and W is its ‘weight’

or

so, it the original object was split like so (1 and 2 being where mass is and 3 being “void” space), this is what it would look like.

NOTE: we subtracted the object ‘C’ as it was “empty” space that was included by the other objects.

Fig. #-C. Calculating the Center of Gravity

From “How to Determine the Center of Gravity of Any Load” by Laura Hatton

### How are these related to game Programming?

Torque and Center of Gravity is related to games programming because they are physics engine properties.

Where torque would be used for any rotating object (whether that starts, accelerates or does not affect the rotation speed) in order to determine its new rotation speed.

Center of Gravity would be used for balancing any object and as a rotation point.

# Conclusion

Summarize the report by restating the reason for this topic and how the key points (covered above) make this topic relevant to Game Programming.

# References

Put all your references here.