

## Movie Physics: The Hulk ~ Project

Name: \_\_\_\_\_

### Inquiry Question

**Comic book characters have always made for entertaining cinema. Great movies pay close attention to the limitations that physics dictates. Does the Hulk push the limits too far when he tosses a tank?**

It's fun to discuss the realism of movies. The animators always push the bounds of what is acceptable. Sometimes they overreach and the film becomes "over the top" and completely unbelievable. This can turn off viewers.

Let's analyze The Hulk with the video clip presented below.



**Instructions**

Using a pencil, answer the following questions. The lab is marked based on clarity of responses, completeness, neatness, and accuracy. Do your best! Please ensure that any data measured (or recorded) includes the appropriate number of significant digits (only one uncertain digit).

This activity is divided into three sections:

- Core – this first section explores only the basic “core” ideas involved in understanding. Students must demonstrate a sound understand with all of their answers in this section BEFORE attempting the next section.
- Mastery – Your instructor will NOT review this section if the Core section above shows any misconceptions. In this section students will make predictions and apply the concepts and ideas learned above. For complete mastery it is expected that data collection and scientific procedures will be as accurate as possible. All work shown should be clear with any units included. Answers should be rounded off to the correct number of significant figures based on the data collected.
- Ace – Once again, your instructor will only look at this section provided he/she is confident that the above Mastery criteria has been met. In this section students will demonstrate a deeper understanding of the concepts through error analysis, experimental design etc. Physics concepts from other units already covered will often be required here.

This Project will be graded according to this [Marking Rubric](#) (link).

**Software Instructions:**

Open the [pdf](#) instructions file and download the *Tracker* software from the link below. Video tutorials on the use of Tracker are included. See Kinematics Free-Fall instructions below for additional support if you need to.

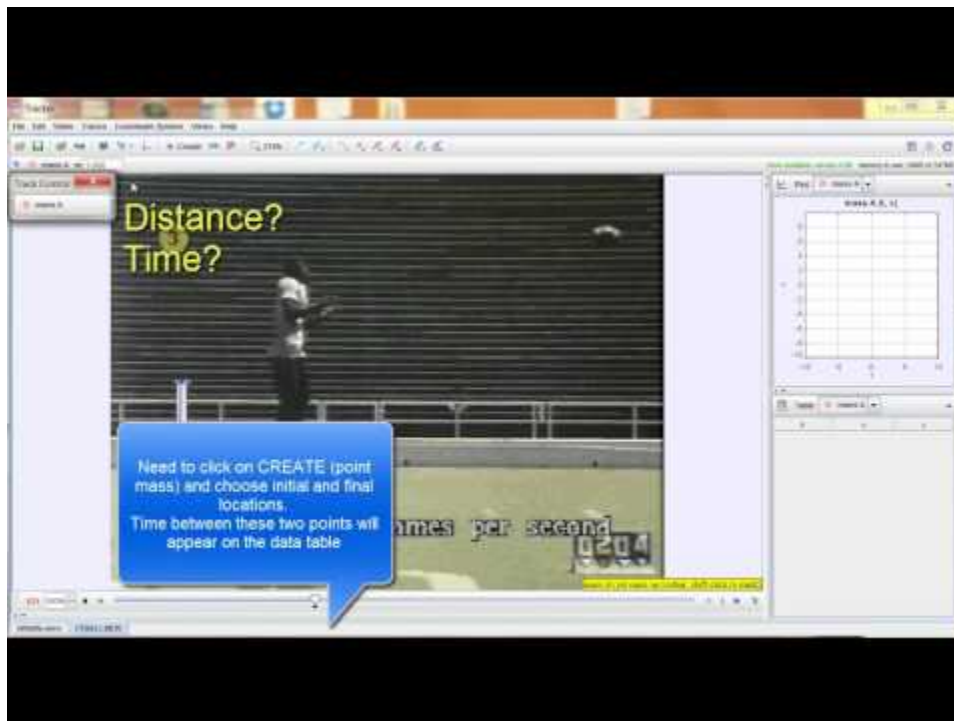
**[Click here for additional pdf Instructions](#)**

**[Tracker Software \(click to install\)](#)**

To get you started quickly we have also created **video instructions**. You may need the *.pdf* above as well for lab-specific data analysis instructions. Follow the links below

For an easy way to take distance, time, and angle measurements use the *Tracker* software to analyze videos (or photos). Watch the video below for a quick tutorial.

<https://www.youtube.com/watch?v=JHzAnPnACKI&feature=youtu.be>



## **Background**

In the lucrative world of movie making scientists are often hired as consultants to ensure that the special effects remain realistic and accurate to please today's knowledgeable and demanding audiences.

You are to analyze the blockbuster movie "The Hulk". Your task is to view and analyze scenes from this movie and determine if the Physics depicted is accurate.

All of the necessary footage can be downloaded directly off of the Physics site. You may also download the "Tracker" software and use its many features to improve the accuracy of your data and estimates. With or without the software you will be required to provide sources for any estimates made. Have fun and don't be surprised if your answers seem ridiculous. It is Hollywood after all.

## Download the Hulk video for analysis...

[Right-Click here](#) and chose *Copy Link Location* for the video showing the Hulk video.



### [Hulk Video](#)

(right click and select copy link location, open is browser to download. Then open the download folder to view the file and change extension to .mp4 - vs. .zzz)

Your video should look like the one below



Having successfully “TRACKED” your tank using the software as described in the instructions, it’s now time to begin our analysis.

## Part 1: Core

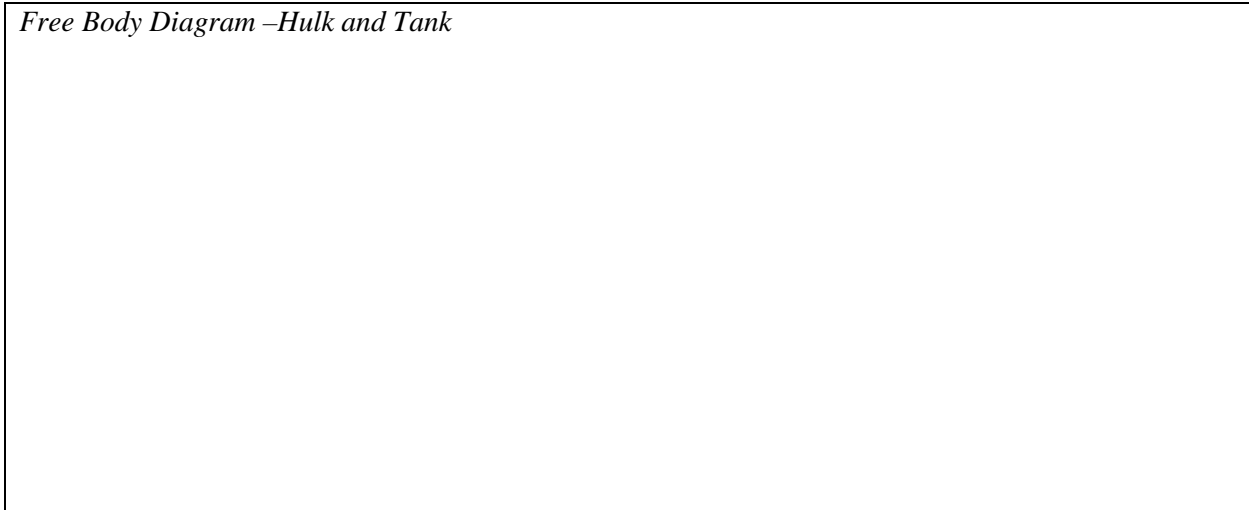
### **Movie: The Hulk**

Download the Hulk video provided and make sure that you have an appropriate player to view the video in. If you use *Tracker* you will have to **scale the video** to some known dimension (like the length of the tank?). Ideally you will need to be able to take measurements of various lengths and times involved. If you plot points on *Tracker* it will give you time values that may be useful.

#### ***Procedure:***

Draw a simple free-body diagram show a side view of the Hulk and the revolving tank. Label all of the forces acting on both the Hulk and the tank.

*Free Body Diagram –Hulk and Tank*



**The Tank:**

The tank is revolving about a point (the Hulk) and must adhere to the laws of circular motion. Isolate the tank below. Sketch the free body diagram for the tank only and label the direction of the tank’s acceleration. Determine the *Equation of Motion* for the tank.

Free Body Diagram – Tank Only
Equation of Motion for the tank:

1. There are two equations we use to determine the centripetal acceleration,  $a_c$ :

Equation 1: $a_c = \frac{v^2}{r}$	Equation 2: $a_c = \frac{4\pi^2 r}{T^2}$
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- a. If we wish to determine  $a_c$  using the videos provided, which formula is more useful? Write your new equation of motion below with the appropriate version of  $a_c$ .

**Equation 3:** \_\_\_\_\_

- b. Justify your choice  $a_c$  above.

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2. Both equations require a value for the radius of the circle,  $r$ . Use the picture below to help estimate what this radius is. *Hint: In Physics we always measure all distances to the centre of mass of the accelerating object.*



3. Label the radius,  $r$ , directly onto the diagram above.
4. Create a table to record all of your data collected. Be sure to reference videos used and websites or sources of measurements used. Estimate the amount of error in each recorded measurement. The first row has been completed as a sample (assuming you need the mass of the tank). Add to the list as needed.

Measurement	Value with error ( $\pm$ )	Method Used	Source
<b>Abrams M1 tank mass, m</b>	<b>(60 <math>\pm</math> 5) metric tonnes.</b> <i>Note: <math>\pm 5</math>kg because we were given masses of various models on the website</i>	<b>Internet search</b>	<a href="https://en.wikipedia.org/wiki/M1_Abrams">https://en.wikipedia.org/wiki/M1_Abrams</a>

You should see from your first free body diagram that the Hulk is being pulled towards the tank by a force **equal and opposite** to the force pulling the tank towards the Hulk. Your goal is to **determine the magnitude of this force** using your equation of motion (*Equation 3*) along with any measurements estimated.

Make sure that any variables used are also labeled directly onto your above diagrams. Be sure to include all appropriate units.

<i>Variables (define):</i>	<i>Equation (Solve for “Inward Force” acting on the tank)</i>

***The Hulk:***

Now let’s look at the Hulk. We can consider the Hulk to be at the centre of the circle. Since  $r = 0$  for the Hulk we can assume that his centripetal acceleration is zero and he is in equilibrium. Draw the forces acting on the Hulk when he is at the centre of the circle. Remember, he is not accelerating so there must be some force balancing the outward force provided from the whirling tank. What force is this?

\_\_\_\_\_ (*Hint: you may have to research any useful coefficients*).

Determine his equations of motion to satisfy his equilibrium condition both vertically and horizontally.

<i>Free Body Diagram: Hulk</i>	<i>Horizontal Equation of Motion:</i>
	<i>Vertical Equation of Motion:</i>



5. The **Normal Force** between the Hulk and the ground (**increases/decreases**) as a result of lifting the tank. **Circle** your choice and consider this fact when solving below.
  
6. Solve for the mass of the Hulk using your equations of motion above. Once again label all variables used directly onto your diagram and provide sources for any estimates utilized.

<i>Variables (define):</i>	<i>Equation (Solve for mass of Hulk)</i>
	<i>Hulk's Mass:</i> _____

**Conclusion:** Comment of your value of the Hulk's mass and discuss the accuracy of your estimate. What were the major assumptions that contributed to errors in your calculations?

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### Part 2: Mastery

1. Using your original data, determine the launch velocity of the tank assuming **uniform circular motion**.

Launch velocity (uniform assumption),  $v_{uniform} =$  \_\_\_\_\_ m/s

2. Using your answer above, determine the maximum range that the hulk could throw this tank.  
Show all work below:

Maximum Range:

Range =  $d_x =$  \_\_\_\_\_ m

3. Discuss some possible forces unaccounted for when we determined the Hulk’s mass. Describe how the addition of these forces would affect the mass calculated. *Hint: Consider the Hulk’s feet interacting with the sand.*

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4. Discuss a more realistic outcome for the tank that might occur as the Hulk grabbed it, and then started spinning it.

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5. How many “g’s” would soldiers in the tank experience as a result of this centripetal acceleration?  
(note: an acceleration of  $9.8 \text{ m/s}^2$  would be  $1g$ , while an acceleration of  $19.6 \text{ m/s}^2$  would be  $2g$ 's)  
Show all work below:

$g_{\text{soldier}} =$  \_\_\_\_\_



2. You may have noticed that the tangential speed of the tank is increasing as the hulk whips it around faster and faster. Devise a way to calculate a better estimate of the final launch velocity of the tank that somehow includes this acceleration. Show all steps and assumptions below.

Final Launch Velocity,  $v_{non-uniform}$  = \_\_\_\_\_ m/s

3. Compare the non-uniform launch velocity,  $v_{non-uniform}$ , to the uniform launch velocity,  $v_{uniform}$  (determined in *Part 2 – Mastery*, question 1).  
**Without re-calculating**, determine the net affect this better estimate,  $v_{non-uniform}$ , would have on the Hulk’s mass. Show your argument below.

4. The scientific community reviewed the film. This scene was heavily critiqued. A respected physicist suggested that the scene would be more accurate if the Hulk grabbed two tanks – one in each arm. Explain how this would improve the “realism” of this event below.

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