Short Video Projects on Physics Education: Video 1

Adam Field[1]

[1] *Department of Physics, Worcester Polytechnic Institute, 100 Institute Rd, Worcester, MA*

INTRODUCTION

This is a transcript of the first video in my IQP project. I hope to teach an introduction to Newtonian gravity.

Duration: 5 minutes

Target Misconception: "Gravity is just what makes things fall down" / "Heavy objects fall faster than light objects"

Learning Objective: Understand that gravity is a universal force of attraction between all masses

1. SCENE 1: THE HOOK (0:00–0:45)

[VISUAL: Camera on presenter, holding a basketball in one hand and a tennis ball in the other]

DIALOGUE:

Hey everyone! Quick question for you: If I drop these two balls from the same height at the same time, which one hits the ground first?

[VISUAL: Hold them up at shoulder height]

[VISUAL: Pause for 2 seconds]

The basketball, right? Because it's heavier?

[VISUAL: Pause for 1 second]

Well... let's find out.

[VISUAL: Drop both balls simultaneously. They hit the ground at the same time. Use slow-motion replay if possible]

They hit at the *same* time! Now, you might be thinking, "Wait, that can't be right. Heavier things fall faster, don't they?"

If you thought the heavier ball would fall faster, you're not alone. This is one of the most common misconceptions in physics, and today we're going to understand *why* things fall the way they do by exploring one of the most fundamental forces in the universe: **gravity**.

[VISUAL: Fade to manim animation]

[MANIM: Title card with "Universal Gravitation" animates in]

2. SCENE 2: SETTING THE STAGE (0:45–1:30)

[MANIM: Voiceover over manim animation]

DIALOGUE:

So what exactly *is* gravity? Let me ask you this: why do things fall "down" in the first place?

[MANIM: Animate a simple ball falling toward Earth]

Most people think gravity is just this thing that pulls objects toward the ground. And sure, that's *part* of it. But gravity is so much more than that.

Here's the big idea that changed everything: **Gravity isn't just Earth pulling things down. It's a force of attraction between ALL objects that have mass.**

[Note: When we talk about the force of gravity, we're referring to its magnitude—how strong the pull is. In later videos, we'll explore how gravity also has direction, making it a vector.]

[MANIM: Animate two masses (circles) with arrows pointing toward each other, showing mutual attraction. Label them m_1 and m_2]

[MANIM: Show Earth and a person, with arrows pointing both ways]

That means Earth is pulling on you... but you're also pulling on Earth!

[MANIM: Hold on the visual - pause to let that sink in]

[MANIM: Zoom out to show multiple objects in a room - phone, desk, person - all with tiny arrows pointing between them]

Your phone is pulling on you. You're pulling on your desk. Every object in this room is pulling on every other object. In fact, you and I are gravitationally attracted to each other right now!

[VISUAL: Cut back to presenter on camera with a smile]

Pretty wild, right?

3. SCENE 3: NEWTON'S BIG DISCOVERY (1:30–2:30)

[VISUAL: Presenter on camera]

DIALOGUE:

In 1687, Isaac Newton figured out the exact rule for how gravity works. He called it the Law of Universal Gravitation, and here's what it says:

[VISUAL: Transition to manim animation]

[MANIM: Equation fades in gracefully]

$$F = G\frac{m_1 m_2}{r^2}$$

[MANIM: Voiceover continues]

DIALOGUE:

Don't worry if equations make you nervous—let's break this down together. This equation tells us the gravitational *force* between any two objects.

[MANIM: Highlight and label each variable as it's mentioned]

F is the force of gravity.

[MANIM: Show two masses with labels m_1 and m_2]

m_1 and m_2 are the masses of the two objects.

[MANIM: Draw a line between the masses showing distance r]

And r is the distance between them.

[MANIM: Show G with a small annotation "very tiny number!"]

That G is just a constant—a really tiny number that makes the units work out.

[MANIM: Animate masses getting larger, force arrow grows. Then animate masses moving apart, force arrow shrinks]

Here's what this equation is telling us: The magnitude of the gravitational force gets *stronger* when objects are more massive, and it gets *weaker* when they're farther apart.

Question 1. DIALOGUE:

Let's test your understanding. If you doubled the distance between two objects, what would happen to the gravitational force between them?

[VISUAL: Pause for 3-4 seconds]

[MANIM: Show equation again with r being replaced by $2r$, highlighting the r^2 term]

DIALOGUE:

If you said the force becomes *one-fourth* as strong, you're absolutely right! That's the inverse square law—double the distance, and the force drops by a factor of four. Great job!

[VISUAL: Cut back to presenter on camera, holding basketball and tennis ball]

DIALOGUE:

Now you might be wondering: if everything is pulling on everything else, why don't I feel pulled toward my desk? Why don't these two balls attract each other?

[MANIM: Show the two balls with a tiny, almost invisible force arrow between them, then zoom out to show Earth with a huge force arrow]

DIALOGUE:

Great question! Look at that equation again. See how G is an incredibly small number? For everyday objects like you, me, or these balls, the masses are so small compared to Earth's mass that the gravitational force between us is *tiny*—way too small to notice.

[MANIM: Display "Earth's mass = 6×10^{24} kg" with the number animating in]

But Earth? Earth has a mass of about 6 trillion trillion kilograms! That's why *Earth's* gravity is the only gravity we notice in our daily lives.

4. SCENE 4: SOLVING THE MYSTERY (2:30–3:45)

[VISUAL: Cut back to presenter holding both balls]

DIALOGUE:

Okay, so now we understand that gravity is a force between masses. But we still haven't answered our original question: why do these two balls fall at the same rate?

Think about it: Earth pulls harder on the basketball because it has more mass. So shouldn't it fall faster?

[VISUAL: Transition to manim animation]

DIALOGUE:

Here's the beautiful part—and this is where Newton's genius really shines. Yes, Earth pulls harder on the basketball. But there's another equation we need to remember:

[MANIM: Write and animate $F = ma$]

Force equals mass times acceleration. Let's think about what this means for our basketball.

[MANIM: Show basketball labeled with mass m_{ball}, with a large force arrow pointing down labeled $F_{gravity}$]

Earth pulls on the basketball with a bigger force because the basketball is heavier.

[MANIM: Show resistance/inertia visualization - perhaps the basketball with motion lines showing it's harder to move]

But—and here's the key—the basketball is also *harder to accelerate* because it's heavier! These two effects exactly cancel out!

[MANIM: Show both equations side by side]

$$F = G\frac{M_{Earth} \cdot m}{r^2}$$
$$F = ma$$

If we put Newton's gravity equation together with $F = ma$, watch what happens:

[MANIM: Animate setting them equal: $G\frac{M_{Earth} \cdot m}{r^2} = ma$]

[MANIM: Highlight the m on both sides, then show them canceling out with a crossing animation]

$$G\frac{M_{Earth} \cdot \cancel{m}}{r^2} = \cancel{m}a$$

The mass cancels out! That means the acceleration due to gravity is the *same* for all objects, regardless of their mass.

[MANIM: Show the final simplified result]

$$a = \frac{GM_{Earth}}{r^2}$$

[**MANIM:** Circle where m would be - show it's missing]

See? No m for the falling object! The acceleration only depends on Earth's mass and the distance from Earth's center.

[**MANIM:** Show famous footage reference - or animate a feather and hammer falling on the Moon side by side at the same rate]

This is why a feather and a hammer dropped on the Moon—where there's no air resistance—fall at exactly the same rate.

[**VISUAL:** Cut back to presenter on camera]

Question 2. DIALOGUE:

Let's test your understanding. If I were standing on a planet that has twice Earth's mass, would objects fall faster, slower, or at the same speed as on Earth?

[**VISUAL:** Pause for 3-4 seconds]

[**MANIM:** Show equation again with M_{Earth} being replaced by $2M_{Earth}$, showing a increases]

DIALOGUE:

If you said *faster*, you're absolutely right! Look at our equation: bigger M means bigger a. Objects would accelerate downward more quickly. Great job!

5. SCENE 5: WRAPPING UP (3:45–4:30)

[**VISUAL:** Presenter on camera in casual presentation style]

DIALOGUE:

So let's review what we've learned today.

[**MANIM:** Show key points appearing as text with icons]

Gravity isn't just "the thing that makes stuff fall down." It's a universal force of attraction between *all* objects with mass.

Newton discovered that this force depends on the masses of both objects and the distance between them.

[**MANIM:** Show the cancellation animation again briefly]

And here's the part that surprises most people: even though Earth pulls harder on heavier objects, those objects are also harder to accelerate. These effects perfectly balance out, which is why all objects fall at the same rate!

[**VISUAL:** Cut back to presenter holding both balls one final time]

Pretty cool, right?

[**MANIM:** Preview animation - show a projectile arc]

In our next video, we'll explore what happens when we throw or launch objects—and discover that projectile motion is just falling... with style.

Thanks for watching, and remember: physics is all around you. Sometimes you just need to look at it from the right angle!

[**MANIM:** Fade to end card with channel/project info]

ACKNOWLEDGMENTS

I would like to thank Professor Noviello and Professor Kafle for their guidance on this project.

Portions of this transcript were developed alongside the assistance of generative AI technology (Claude), which gave me feedback on the pedagogical presentation.