CMU Engineering Outreach Presentation Plan:

Presenters: Ravesh Sukhnandan

Grade Level: 9-12

Standards Connection(s): _____

Teaser: For the most part, we don't need to actively think about what muscles we need to activate in order to do it. But surely something as complicated as walking can't be as effortless as it appears? Surely out muscles must work extremely hard to support our weight and keep us moving forward? As we will find out, you can walk quite far without moving a single muscle.

Objective: After going through this lesson, students will:

- Be able to understand how bipedal locomotion takes advantage of naturally occurring forces (friction and gravity) in order to locomote
- Able to create a free body diagram of the forces acting on the bodies and relate to them Newton's Laws on motion
- Understand why it is necessary for some anatomical features to be present in order to enable locomotion.

Vocabulary/Definitions:

- Locomotion – "Any of a variety of movements among animals that results in progression from one place to another"
- Friction – "Force that resists sliding or rolling of one solid object over another."
- Newton's Second Law – "Three statements describing the relations between the forces acting on a body and the motion of the body"

Materials: *What will be brought to the classroom?*

- 3D printed kits for the passive dynamic walkers (PDW)

Kids need to bring:

- Some exercise books or text books on which to place the ramp for the PDW.

Classroom Setup: *Projector is needed for slideshow. A blackboard may be used if a projector/screen is not available. Students may work in groups of 2-4 to build and test their PDW depending on kit quantity.*

Classroom Visit:

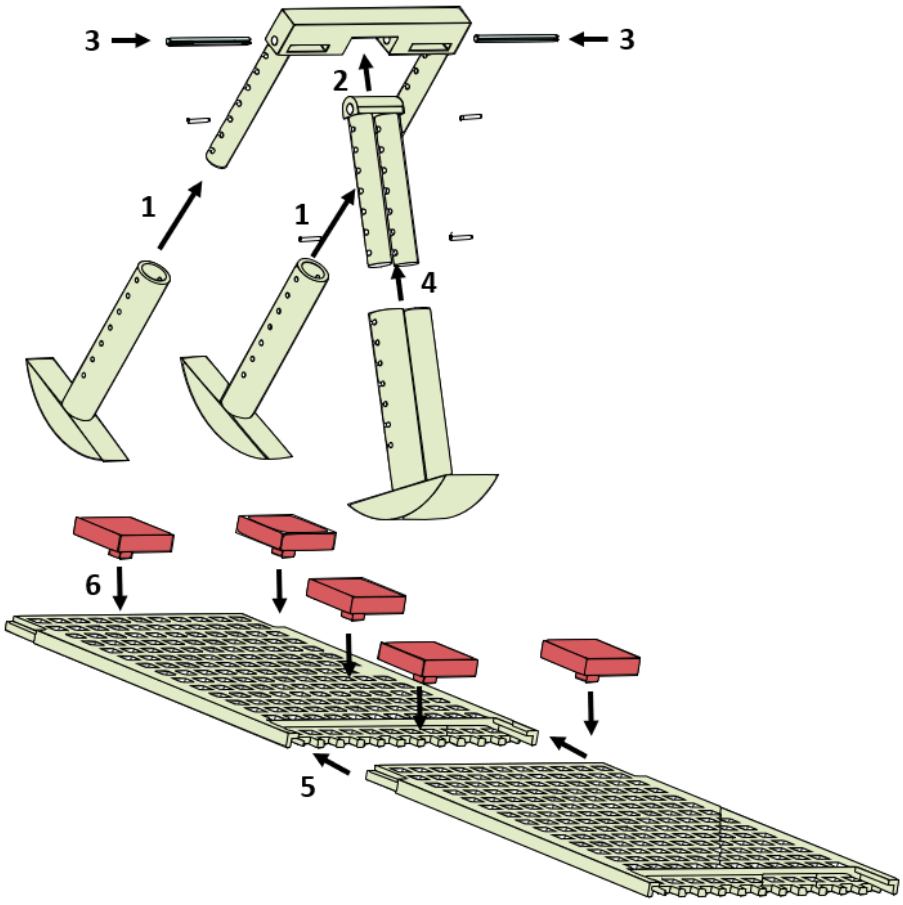
Write out for both 1 hr, and 1.5 hr learning experiences. Sample below is for a 1 hr lesson. For a 1.5 hr lesson, extend the learning experience.

1. **Personal Introduction:** 5 Minutes
   Take a few minutes to break the ice between students and the instructor. Instructor will ask if they have to actively think about which muscles they move when they are walking or moving. Instructor will ask the class if anyone plays sports or watches sports.

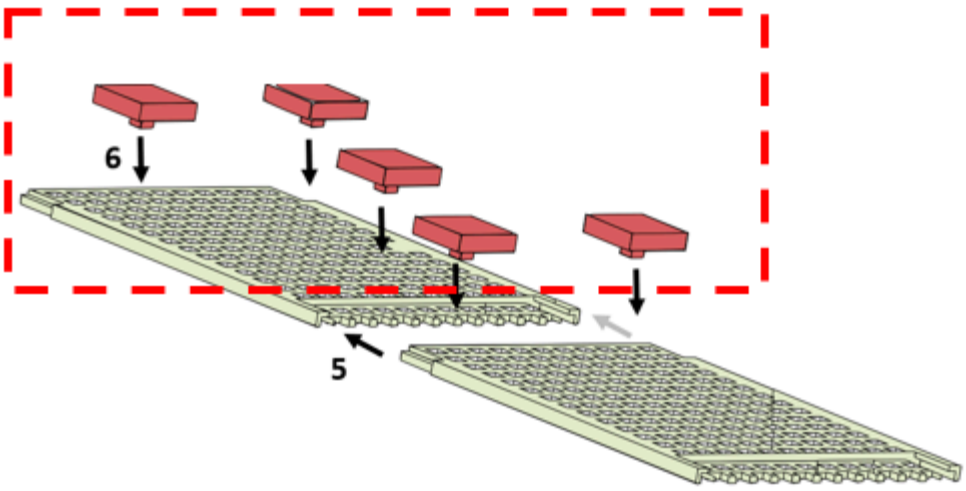
   Topic Introduction: 10 Minutes
   (Lead in from student experiences). Instructor introduces what locomotion is, why it is important and the diverse forms of locomotion found in the animal kingdom. It is important to study locomotion because it helps us to know how to make athletes better, or design better exoskeletons, or build better robots. But for something that we do so effortlessly, locomotion has been notoriously hard in robots (show slide with robots falling over). Why is that? How can these very complicated systems fail so spectacularly? Well, we can use the intersection of physics and biology to help us understand how we move, and that actually, we can walk quite well without needing to excite a single muscle.

   I will then introduce the students to videos of the passive dynamic walkers, and what we will build today.

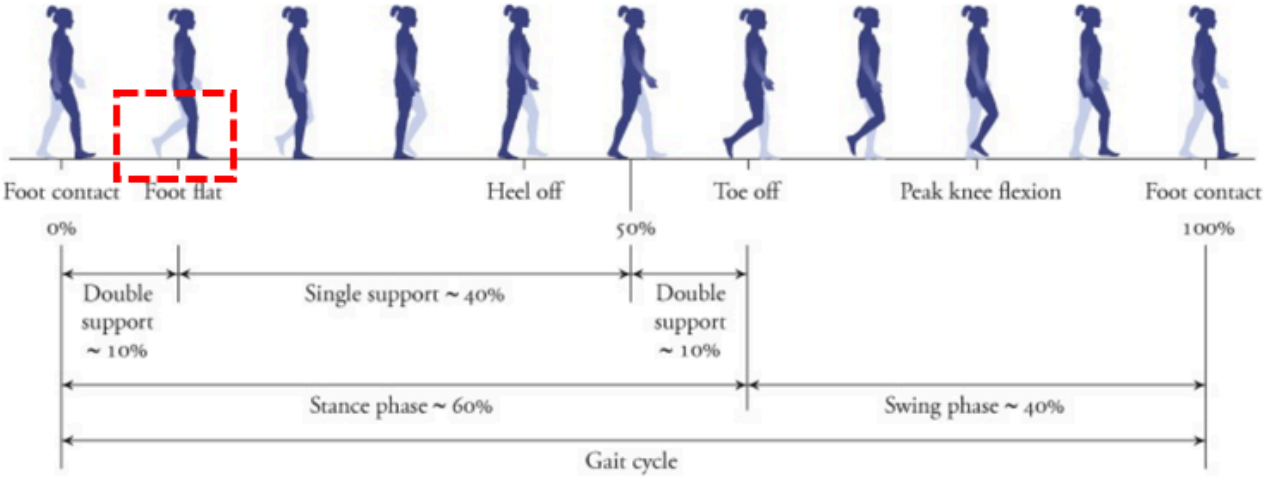
2. **Learning Experience(s):** 30 Minutes
   First 10 minutes:
   Walk students through the kit and how to assemble the passive dynamic walkers:



Next 3 minutes:
Ask students why we need the red pads.

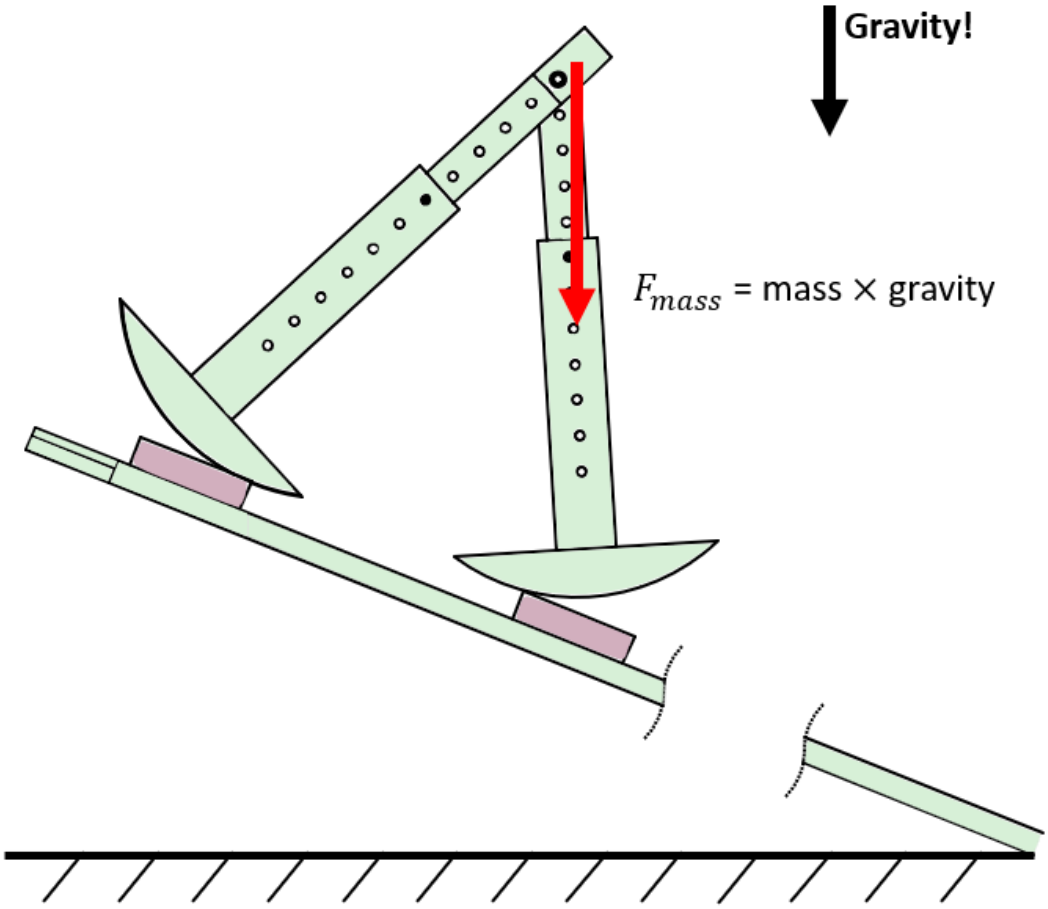


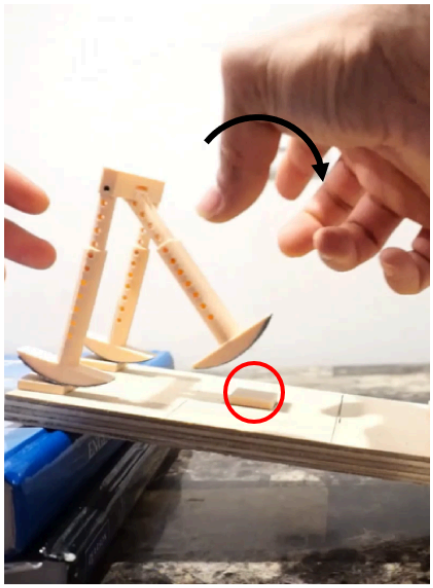
Ans: Humans have knees so during the "swing phase" of walking, we can bend our knees so our feet don't drag on the floor. Our walkers don't have the ability to bend, so we need to elevate them somehow!

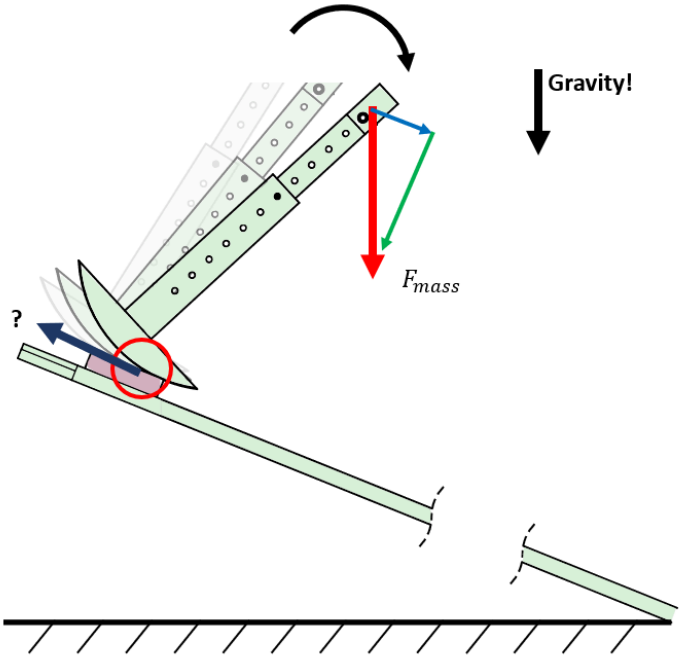


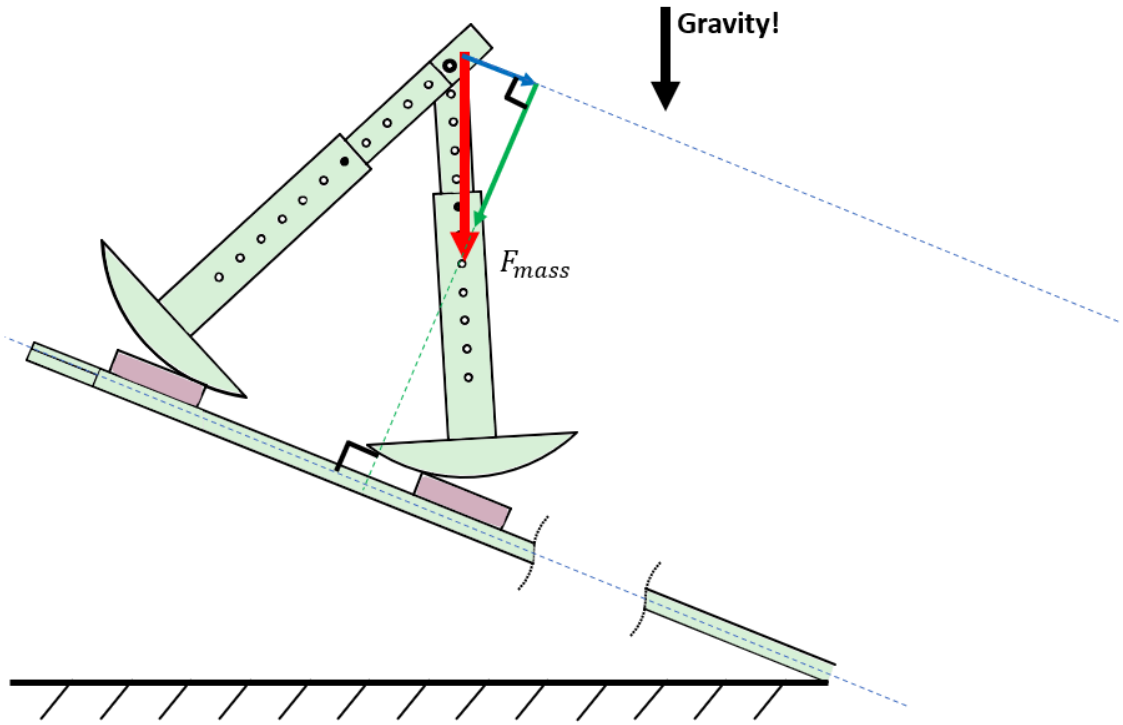
Next 5 minutes: Investigation of contact between the walker's feet and the pads.
Ask the students to try to have their walkers walk down their ramp. Do they find that the walkers are sliding down the ramp? Why do they think that is?

Introduce them to the concept of a free body diagram, and walk through what forces are acting on the walker

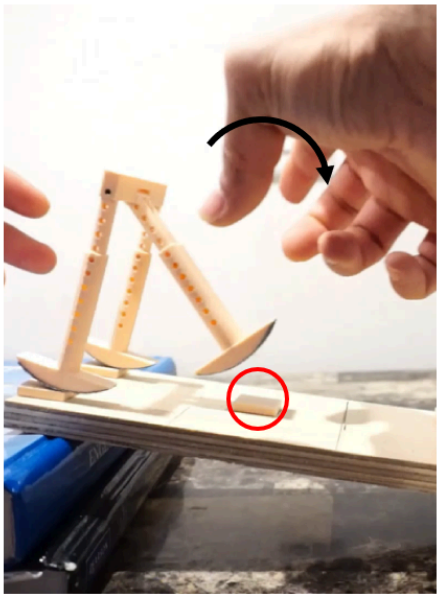

Gravity!
F_{mass} = mass × gravity

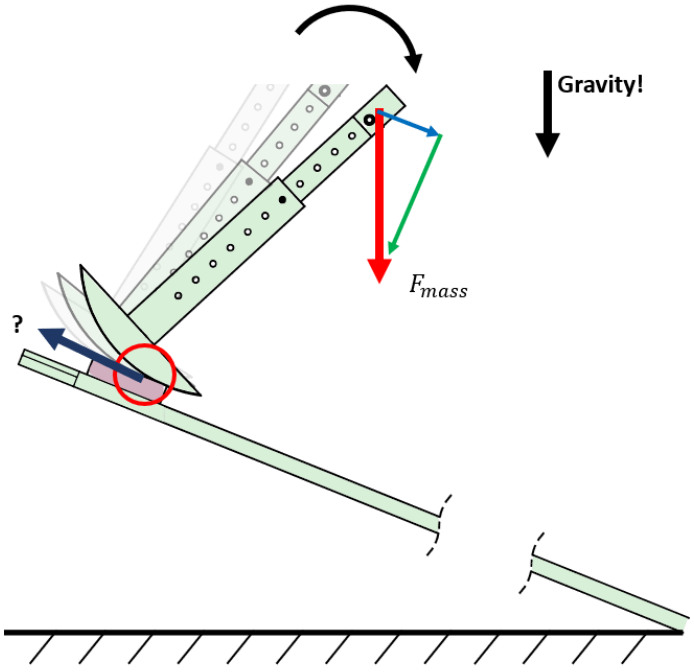



Gravity!
F_{mass}
?



Next 7 minutes: Introduce the concept of friction, and why it is critically important in many different forms of locomotion.





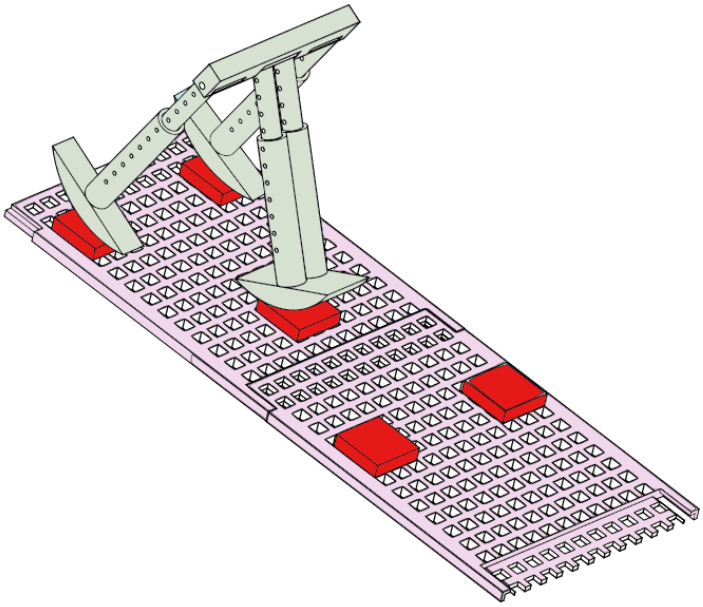
Provide a basic model of frictional force: F_fric = mu*F_normal

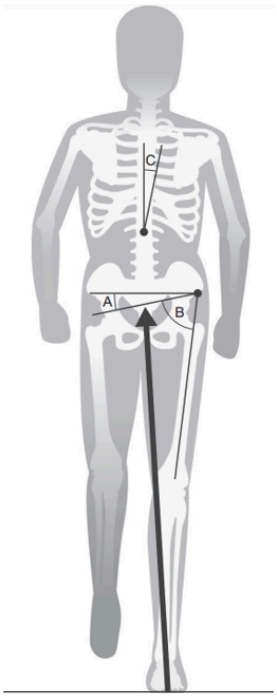
Tell them they can now add the sandpaper to the “soles” of the passive dynamic walker to increase friction coefficient.

Adjust the ramp and the walker until they can successfully get the walker to walk down the ramp.

Next 5 minutes: Playing around with the dimensions of the walker by adjusting its height and the position of the pads. Do they find a sweet spot where the walker walks very well? What happens if the legs are too short or too long?

Ask them why does the walker need "3 legs" instead of two for humans.
Ans: We can shift weight to one leg and stay balanced. That requires muscular coordination! The walker doesn't have that:





3. **Wrap-up: Sharing Experiences** 5 Minutes
   Ask students what their observations and experiences were.

4. **Connections & Close:** 5 Minutes
   Show kids the video of NC State "A spring in the step" where engineers are taking many of the ideas of using "passive forces" to help make better exoskeletons and prostheses.

   Tell kids that not only is engineering cool, but it also can make an incredible impact on the community.
   - **Provide all students + teacher with a CMU Engineering sticker**

Follow-ups for After Presentation:

Suggestions for teacher activities post-lesson:

- Suggestions for activities, websites, and connections for additional learning

- Attachment of all worksheets, handouts, and visuals used in the presentation