**Math Actually Works**! **OTF-OAPT 2018**

1. **A textbook question.** “A spring of force constant 22 N/m is compressed by 3.5 cm and shoots a 7.5 g eraser across a desk. The force of friction is 42 mN. How far will the eraser slide?” Is this a realistic question? I have not managed to simulate it.
2. **12 Bungee Jump:** A basket is attached to a bungee cord made of many elastic bands to make a thrill ride for some mice. What is the maximum mass you can put in the basket, so that falls from the ceiling and just misses the floor?

The solution involves dynamic loading and conservation of energy (elastic to gravitational).

mgh = ½ k x2 therefore m = ½ k x2/gh.

The value of k can be calculated from gently hanging a known mass on the bungee, measuring how far it stretches and using kxs = mg. This is static loading and the value of x is smaller than if the mass was dropped.

When measuring the values of h and x for the bungee jump students must include the reduced distances due to the height of the basket itself.

Note: The behaviour of elastic bands is roughly linear as long as you don’t stretch them past triple their length.

1. **Physics 11 and 12: Rockin’ Pendulum Part 1:** Calculate how long a string you need to swing in time with the music.

A good piece of music for this is Queen’s song “We will rock you” because it has a really obvious beat. I measured roughly 20 beats in 14 s. That means that one beat takes 0.7s. I chose to make this the time for half a period, so the pendulum will swing back and forth in 1.4 seconds. Using the formula, you get a length of 0.5 m. That length worked rather well – but should be done two digits of precision. What other songs would work well?

1. **Physics 11 and 12: Rockin’ Pendulum Part 2:** Calculate how much mass you need to put in the basket attached to a spring to match the music.  
   This one is more complicated because the spring itself has significant mass which is also oscillating. This is complicated by the fact that the top part of the spring is motionless and the bottom part is moving as much as the attached mass. Students will find that their calculated period is quite different from the actual period. They could take the actual period and calculate what the effective mass is and compare it to the spring’s mass plus attached mass.
2. **Physics 12 Conical Pendulum Part 1**: A large dense mass (or a flying pig) is on a string and swinging as a conical pendulum. Using measurements from the photograph, calculate what its period must be. Draw a force diagram and a diagram of the spatial dimensions. From F = ma, you get that

**mg tan()** = m 4 **r/**T

therefore T= 4r/ **tan()**

It is easy to measure the angle, but measuring the radius is tricky unless a ruler has conveniently been included in the photograph. A second photo could be taken with a meter stick in place or some object in the background could be measured. The radius should be measured to the centre of the object, not to the end of the string.

Comparing the calculated period with the actual period is much simpler with a flying pig because it always has the same period and angle. If you are using a mass on the end of a string, use a very long, non-stretchy, light string and a heavy, dense mass so that the orbit does not degrade really fast.

The flying pigs can be found at Arbour scientific for $10 <https://www.arborsci.com/nsearch/?q=flying+pig> or Sergeant-Welch [https://www.sargentwelch.com/store/product/20912786/flying-pig for $13](https://www.sargentwelch.com/store/product/20912786/flying-pig%20for%20$13).

**Conical Pendulum Part 2 - PI Mystery Mass:** A rubber stopper is swinging around using a plastic tune, string and hanging mass as shown. Make measurements of the motion to determine the ratio M/m. The apparatus for this activity can be found here <https://www.sargentwelch.com/store/product/8869449/centripetal-force-kit> $12

This problem came from the Perimeter Institute of Theoretical Physic’s free resource that looks at circular motion and dark matter. It is similar to how astrophysicists determine the mass of starts by measuring the motion of objects that orbit them. (Note: In the astronomical problem the mass of the orbiting mass does not matter and so M can be determined not just M/m). For more details go to this link and get the free resource – video, activity sheets and extra information for teachers.

<https://resources.perimeterinstitute.ca/collections/featured/products/evidence-for-climate-change?variant=12375510089806>

Draw a force diagram and a diagram of the spatial dimensions. From F = ma, you get that

**Mg sin()** = m 4 **L sin()/**T

therefore M/m = 4L/ gT

1. **Physics 12 Cart Jumping**: Measure how far you can do a standing broad jump. Calculate how far you could jump from a cart that another student is sitting on.

If the cart is not loaded and you can do this at all, the cart will zoom backwards and you will go almost nowhere relative to the ground. What if a student sits on the cart?

Your speed relative to the surface you jump off of is roughly constant and vcart + vstudent = v.

Also, momentum is conserved, therefore mcart vcart = mstudent vstudent. Substituting and simplifying, yields vstudent = v mcart/(mcart + mstudent). The distances should be proportional to the speeds relative to the ground (assuming that the person can actually jump equally well in each situation). <https://www.arborsci.com/human-dynamics-cart.html?ff=4&fp=436> $160 US.

1. **Physics 11 A Falling Metronome:** How far apart must you attach nuts to a string so that they hit at five 0.2-s intervals?

d = ½ g t2 You might want to introduce this problem by showing a string with nuts evenly spaced and asking what they will sound like as they hit.

Students should tie a nut to one end. The furthest nut hits after 1.0-s, so the separation of the end nuts should be 4.9 m. A convenient way to attach the nuts is to stick a loop of string through the hole of the nut and then tighten it around the nut. This allows you to loosen and reattach the nuts easily. However this takes up some of the length, so you should attach the 0.2-s nut first and then the 0.4-s nut etc. Each group should get at least 5.5 m of string and six nuts. The sound is easier to hear if the nuts land on a metal cake tin or something similar. You will need a stairwell or similar to get the needed height.

1. What are other examples where math works?

**Barge Competition**: <http://www.tevlin.ca/roberta/Engineering%20Contests/Barges/barges.htm>

Use calculations of volume to predict how much a container can float. This can be used with in grade 9 science (density) and grade 9 math (volumes of regular solids). The rectangular barge contest can be used as a max-min problem in grade 12 calculus.

**Spring Surprise**: <http://newsletter.oapt.ca/files/spring-surprise.html> or <http://www.tevlin.ca/roberta/Engineering%20Contests/Spring%20Surprise/Spring%20Surprise.htm> This uses small springs as projectiles and is perfect for projectile motion and conservation of energy in grade 11 physics. In grade 12 physics you get to use Hooke’s law and projectile motion at different angles.