# 2000–2001 Physics Olympiad Preparation Program

— University of Toronto —

*Problem Set 2: Mechanics*

*Due November 27, 2000*

**1) Take your best shot**

Evangeline, an Olympic biathalon competitor-in-training (who hopes to use her keen grasp of kinematics to win gold), keeps a water supply on her training course: on top of a 10 meter-high water tower platform sits a 10 meter-tall cylindrical drum of water, 3 meters in diameter. Unfortunately, the pipes to the drinking fountain below have frozen solid. Evangeline skis up to a point 5 meters away from the base of the tower, and with her last round she uses her target rifle to shoot a small hole in the wall of the water drum.

Where, precisely, on the drum should the hole be so that she can have a drink without moving from the place where she stands? *[Sal]*

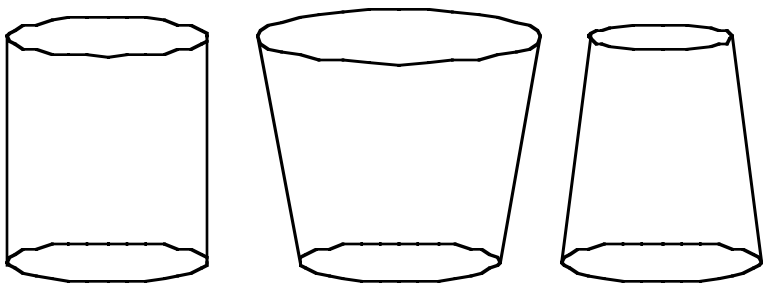
**2) The fountain of (misspent) youth**

Sukumar has accidentally backed his pickup truck into a fire hydrant, and broken it off at ground level (oops!). Water gushes straight upward at a rate of 150 kg $s^{-1}$, and with a speed of 20 m $s^{-1}$. Suku tries to fix things by holding a nearby garbage can over the flow, but finds himself and the can lofted into the air on the water flow.

If Suku weighs 60 kg, and the garbage can weighs 2.5 kg, what is the height that he's waving to his friends from, when the police get there? *[Yaser]*

**3) Huh? Hmmm…**

Consider three containers, as illustrated at right, each with the same area A at its base, and each with height H. The first one is a cylinder, and the other two are tapered. The area of the tops of the other two vessels are 2A and A/2.



a) If all three containers are filled with water, what's the water pressure at the bottom of each? What total force does this then exert over the whole bottom plate of the container?

b) If the containers of water are

each put on a weigh-scale, individually, what weight will the scale show for each? Treat the containers as being very thin-walled, and essentially massless. Only the bottom plate touches the weigh-scale, so why is the measured weight different from the force found as area × pressure you calculated in part (a) ?

Remember that balance shows the force which is exerted on it. *[Yaser]*

**4) All aboard!**

a) A freight train traveling with an initial speed of 65 m $s^{-1}$, cuts its engine and coasts 8 kilometers along a flat track before finally coming to a stop. Calculate the train's coefficient of rolling friction. Is this a value for the whole train, or for each railroad car?

b) A locomotive is pulling an empty 15.0-m-long hopper-loader car at a constant speed of 1.00 m $s^{-1}$. The mass of the locomotive and empty car is about 75,000 kg. As the hopper-car moves along the track it passes under a grain dispenser that pours grain into the car, at a rate of 1000 kg $s^{-1}$. The grain dispenser only operates when the car is beneath it. How much work does the locomotive do while the hopper-car is being filled? Assume that the coefficient of rolling friction is the same as calculated in part (a). *[Brian]*

**5) Java jump-up (eeyow!)**

A few years ago McDonald's™ was sued by a woman who was badly scalded when the cup of hot coffee she was holding between her thighs — while driving — spilled. The woman won the suit, and since then their coffee cups include a printed warning on them that the presumably hot coffee inside is really hot.

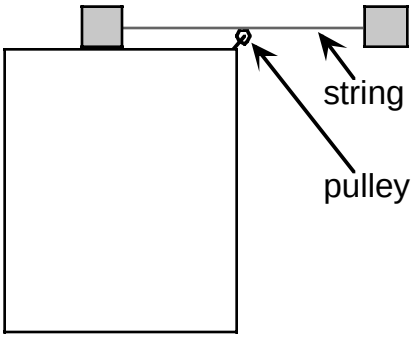
So when the makers of the *Java Jumpstart Commuter Mug** recently came out with a new model, we at POPTOR suggested they have it evaluated by *Deepee-Deetee Consultants Inc*., a group of OAC Physics students, who evaluated the mug's stability on the dashboard of a moving car.

The physics-consultants found that the mug's stability depends significantly on how much coffee is inside. Find the height or coffee level in the mug for which the mug of coffee is least likely to tip when the car accelerates. The mug is 20 cm tall, has a radius of 6 cm, and weighs 200 grams (1/4 of which is the weight contribution of the bottom of the mug) *[Sal]*

*[*a fictitious company. If you find the first true storey unlikely, compare with other true stories of human fallibility at the irreverant Darwin Awards homepage, http://www.darwinawards.com]*

**6) Weight! Bob!**

In science, either experiment or theory can lead the way in discovery. But it pretty much isn't *finished* science until both experiment and theory come together. Here's one example where a simple experiment can tell you the answer you might not be able to guess theoretically — and steer you in the right way to think, in order to understand.




Two identical weights are connected by a 1 m string. To begin, one weight is set on a frictionless table, and the second is held as in the picture, with the midpoint of the string between them draped over a massless frictionless pulley.

If the second weight is dropped, which happens first:

- does the first weight slide along until it hits the pulley, or
- does the second one swing around until it hits the side of the table?

*Try this in an experiment,* to find the true answer, and then see how well you can explain it by theory. Try whatever you like to make things practically frictionless as given — but tell us what *you* did in *your* experiment, to approximate these ideal conditions, and then carefully describe what you measured.

HINTS: To make the first weight practically frictionless on the table, you might try two child's wooden cars with wheels. Or you might be able to use an air-rail at school for the table and tie together two identical air-rail cars for the weights. Or perhaps a dry-ice puck on the table would be practically frictionless, and you could tie it to an equal weight to drop at the side. The frictionless pulley can be nearly any small lightweight wheel (no inertia!), or perhaps teflon tubing rotating on a nail — or you might use teflon-coated electronics wire to connect the weights, and then a smooth round edge on the table to slide over with little friction. *[Yaser, Robin]*

CHECK THE POPTOR WEB PAGE for other hints, and any corrections we might post:
www.physics.utoronto.ca/~poptor