PHY151 Practical Questions for Nov 14 to 18

1. A hoop and a disk are released from the top of a ramp of angle θ. They roll down a distance L along the ramp (so the height is $h = L\sin\theta$). They roll without slipping (so the static friction is high). Ignore rolling friction. Find their speeds at the bottom of the ramp. Find their accelerations. Which one wins?

   You will need to know that the moments of interia are $I = mr^2$ for a hoop of mass m and radius r, and $I = \frac{1}{2}mr^2$ for a disk of mass m and radius r.

   Finally, explain why the winner is the winner. Ideally, you can explain it two different ways: one way using forces and torques, and one way using energy.

   Note: doing this question before question 3 will be helpful.

2. Practise integrals by finding the x-component of the centre of mass, and the moment of inertia around the y-axis, of the triangle pictured below.

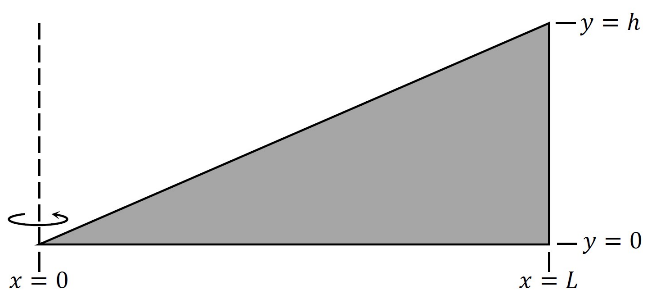
   First: explain why the linear density $\frac{dm}{dx} = \lambda(x) = Ax$ where A is an unknown constant. That is, why must the density be a linear function in distance from the point at $x = 0$?

   Next: find the value of A by setting $\int dm = M$.

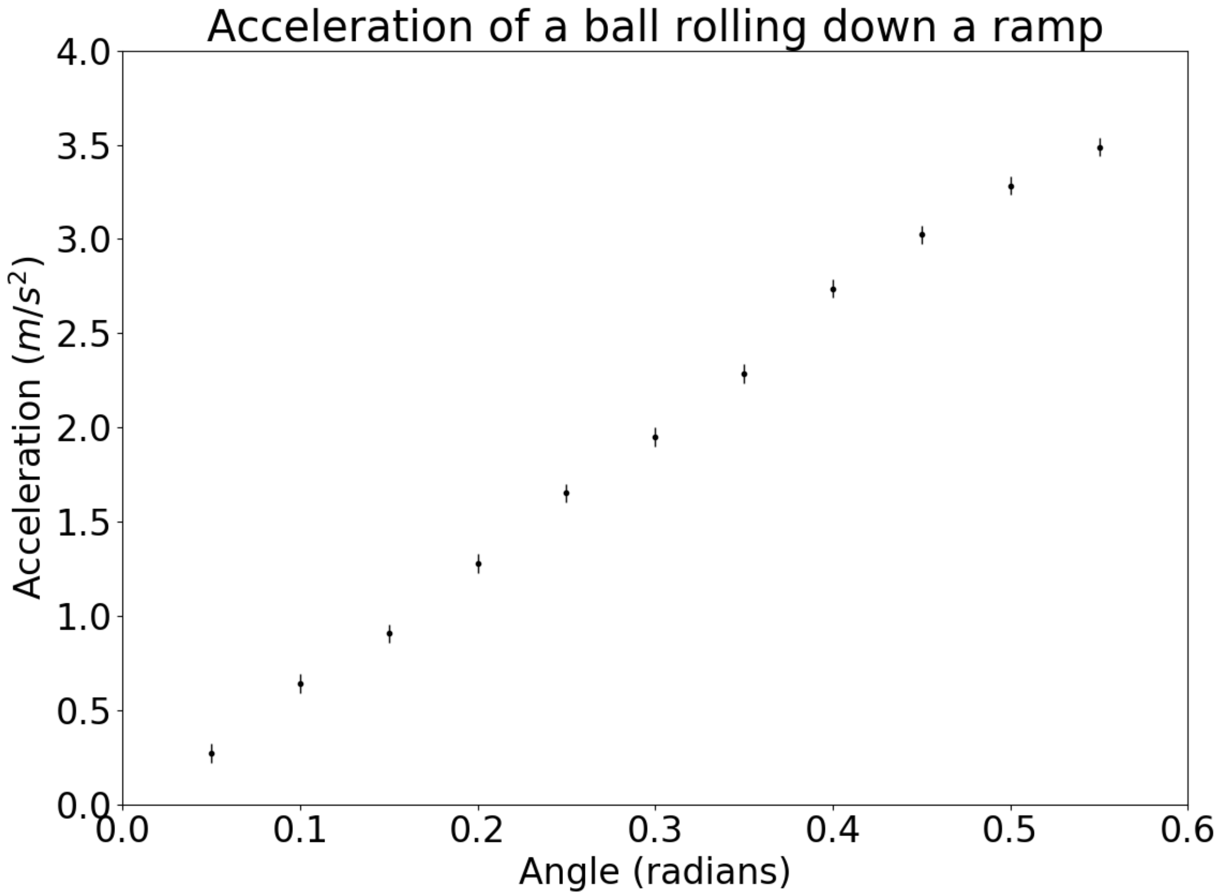
   Now: find the centre of mass by finding $x_{CM} = \frac{1}{M}\int x\,dm$.

   Finally: find the moment of inertia for rotating the triangle around the y-axis by finding $I_P = \int x^2\,dm$.

   (If you want more practice, the moment of inertia around a vertical line passing through the centre of mass is found by integrating $I_{CM} = \frac{1}{M}\int(x - x_{CM})^2 dm$. The parallel axis theorem predicts the relationship $I_P = I_{CM} + Mx_{CM}^2$.)



3. Data analysis question: A steel ball (radius 1.0 cm, mass 33 g) rolls down a ramp of varying angles. Its acceleration is measured for each angle and presented in the graph below. Assuming the moment of inertia can be expressed in the form $I = Xmr^2$, what is the value of X based on the data? *Note:* you might want to do question 1 before doing this question.



4. Modelling question: A steel (density around $7800\,\mathrm{kg/m^3}$) flywheel is a rotating cylinder which stores energy. There are engineering challenges like reducing friction and making sure it doesn't rotate so fast that the steel breaks and it explodes. Assume this can be solved provided that you make sure $\omega r < 100\,\mathrm{m/s}$. How much energy could be safely stored in a flywheel which fits inside the trunk of a car? Evaluate your answer in terms of whether flywheels should be seriously considered as energy storage for cars. *Note:* a cylinder is the same as a disk in terms of moment of inertia. This value was given in question 1.

   If you have some extra time, consider the impact of having this flywheel (a.k.a. a gyroscope) in your car in terms of angular momentum issues when, for example, driving over a round hill. Energy storage is not the only consideration with flywheels.