# General Physics I–Honors: PHYS 101H (Fall 2023)
# Quiz 7–solutions

Chris Monahan
William & Mary

## Instructions

In this quiz you will apply your understanding of angular momentum, rotational motion and static equilibrium. Read the following instructions carefully.

**DO NOT TURN OVER THIS SHEET UNTIL INSTRUCTED.**

This is a **group quiz**. You **must** work in pairs or in a group of three. Working alone or with a larger group will score zero.

Please write your names on the quiz. All pair or group members should write their name on the quiz and **submit one quiz per pair or group**. You will all receive the same grade for your submission.

You have fifteen minutes to attempt all three questions in this quiz. One question is multiple choice.

You may use electronic calculators.

You may **not** use:

- any formula sheets or notes;
- electronic devices, including phones, tablets and laptops (unless previously arranged);
- textbooks or other reference resources;
- course notes or slides.

**Question 1** **4pts**

Consider a ball that rolls down a plane (which has friction and is at an angle $\theta$ to the horizontal) without slipping. And consider a block that slides down a different, frictionless plane inclined at the same angle $\theta$, with respect to the horizontal. Is the linear acceleration of the centre of mass of the ball smaller, larger, or the same as the linear acceleration of the centre of mass of the block? Explain your reasoning, in full sentences. [Hint: there are two reasons for the correct answer!]

**Solution 1**

The linear acceleration of the ball is **smaller** than that of the block, for two reasons. First, friction reduces the net force acting down the plane and therefore decreases the linear acceleration of the ball. Second, the ball will roll down the plane and therefore some of the gravitational potential energy will be transferred to rotational kinetic energy of the ball and the linear speed of the ball will be lower (because its kinetic energy is lower). In contrast all of the gravitational potential energy of the block will be converted to linear kinetic energy.

**Question 2** **2pts**

A motorcyclist makes a jump over a long row of cars. Right after she leaves the takeoff ramp, she notices that her motorbike is angled slightly upward and has zero angular velocity. This is a problem! If this angle is maintained, she will not be able to land smoothly on the ramp, because the motorbike should be angled slightly downwards on impact with the ramp. What is the **best** way for the rider to correct this problem in the air?

1. Lean forward;
2. Lean backward;
3. Hit the gas;
4. Hit the brakes.

**Solution 2**

The answer is $\boxed{\text{d}}$. The wheels spin very quickly in the forward direction at takeoff, so they have a large angular momentum. If the brakes are applied, then the angular momentum of the wheels is decreased, but since there are no external torques, the total angular momentum must be conserved. Thus the angular momentum is transferred to the main body of the bike, which will cause the bike to rotate forward, as needed.

Note that you can also lean backward to achieve the same effect, but it will be much harder for the rider to stay on the bike when it lands, and it has a much more limited effect. The brakes can be applied over a long period of time, for as long as is needed to achieve the needed rotation.

**Question 3** **4pts**

Is it possible for a ladder to lean statically against a wall at an angle of $60°$ when there is friction with the wall (assume the coefficient of friction is very large), but not with the ground? Explain your reasoning, in full sentences.

**Solution 3**

**No**. It is not possible for the ladder to remain in equilibrium in this position, because there is no horizontal force to oppose the horizontal force from the normal force on the ladder where it rests on the vertical wall. Thus the ladder must accelerate horizontally, or the normal force from the wall must be zero. If the normal force from the wall is zero, then the friction on the ladder from the wall is also zero (because $F_{\leq}\mu N$) and there is no vertical force acting on the ladder, except the normal force from the floor and the weight. This normal force therefore exerts a net torque on the ladder around its centre of mass and this means that the ladder cannot be in equilibrium.