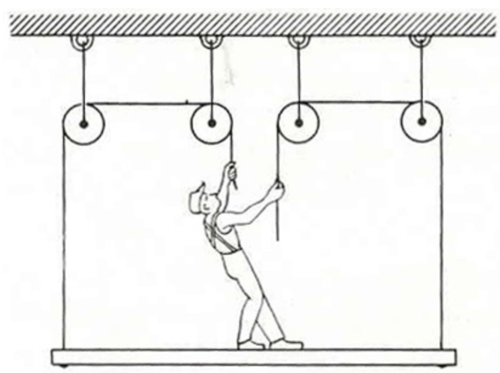
Problem Set 5

Applications of Newton's second law

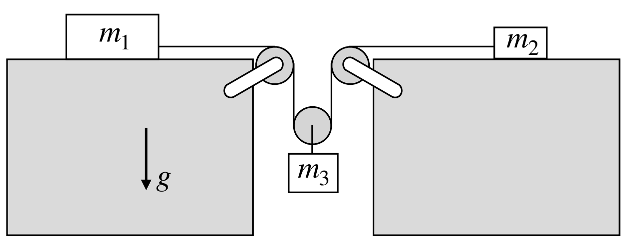
PHYS-101(en)

1. Painter on a platform

A painter of mass m_1 stands on a platform of mass m_2 and pulls himself up by two ropes that run over massless, frictionless pulleys as shown. He pulls down on each rope with a force of magnitude F and accelerates upward with a uniform acceleration. Find this uniform acceleration a.



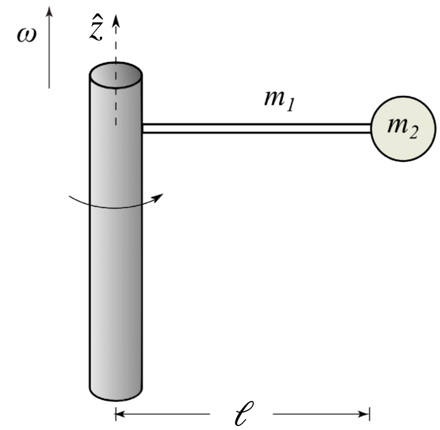
2. Blocks and pulleys



Consider the system shown above, where $m_1 > m_2$, the pulleys are massless and frictionless, the rope joining the blocks is massless and inextensible, and the downward acceleration of gravity is g. The three blocks are made from the same material, as are two tables. As is typical, the coefficient of static friction between the blocks and the tables is greater than the coefficient of kinetic friction, $\mu_s > \mu_k$.

1. Imagine that, when the system is released from rest, you know block 3 accelerates downward with a constant magnitude a, but only one of the other blocks moves. Which block does not move, and what is the magnitude and direction of the friction force holding it back?
2. Now consider the case where, after the blocks are released from rest, all three of them begin to move. Find the acceleration of all three blocks and the tension in the rope.

3. Tension in massive rotating rope



One end of a uniform rope of mass m_1 and length ℓ is attached to a shaft that is rotating at a constant angular velocity of magnitude ω. The other end is attached to a point-like object of mass m_2. Find the tension in the rope $T(\rho)$ as a function of the distance from the shaft ρ.

Assume that the radius of the shaft is much smaller than ℓ. You may also assume the shaft is rotating fast enough that the mass and the rope are horizontal. Express your answer in terms of the variable ρ and some or all of the following parameters: m_1, m_2, ω, and ℓ.

4. Racing around a turn

You and a friend are racing cars (with mass m_1 and m_2 respectively) around a circular, flat turn. You are neck-and-neck with one another (i.e. at the same angular position). But you have the inside lane such that you are turning with a radius R_1, while she is turning with a somewhat larger radius $R_2 > R_1$. Unfortunately, she's going faster, traveling at a constant speed v_2, while you're only traveling at a constant speed of $v_1 = v_2 R_1/R_2$! From your reference frame (i.e. facing forwards in your car), what is the net force acting on your friend's car? Which fictitious forces are contributing? What acceleration do you perceive her as having?

5. Homework: Angular speed of coins

Two identical coins, each of mass m, are stacked on top of each other at the rim of a turntable (a distance R from the center). The turntable turns at constant angular speed ω and the coins ride it without slipping. Suppose the coefficient of static friction between the turntable and the bottom coin is given by μ_1 and the coefficient of static friction between the two coins is given by μ_2, where $\mu_2 < \mu_1$. Let g be the gravitational constant.

1. What is the magnitude of the radial friction force exerted by the turntable on the bottom coin?
2. As the angular speed increases, which coin slips first or do they both slip at the same instant? What is the maximum angular speed ω^{max} such that no slipping occurs?