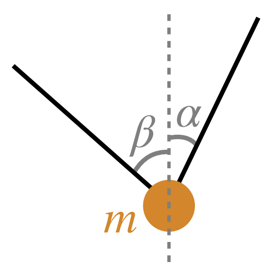
Problem Set 3

Free body diagrams

PHYS-101(en)

1. Balancing forces

A ball of mass m is suspended in the air by two cables as shown below.

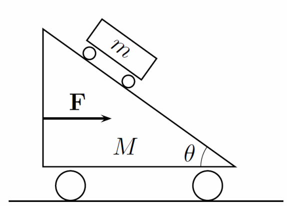


1. List the forces exerted on the ball.
2. Project these forces into a Cartesian coordinate system.
3. The ball is static and does not undergo any acceleration. Determine the magnitude of each force as a function of m, the gravitational acceleration g, α, and β. What happens when $\alpha = \beta$?

2. Triangular trolley

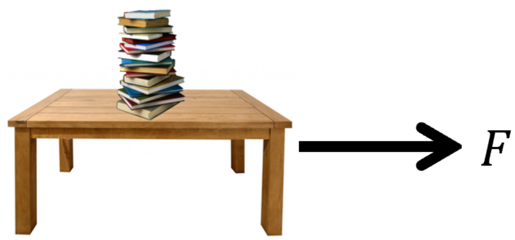
A triangular trolley of mass M has a hypotenuse which makes an angle θ with the horizon (see diagram below). A second smaller trolley of mass m can move freely on the hypotenuse of the triangular trolley. We assume there is no friction and that the two trolleys can move freely. An external force is applied **on the triangular trolley**, which keeps the smaller trolley at a constant height (i.e. immobile relative to the triangular trolley).

1. Draw the free body diagram for each trolley.
2. Determine the magnitude of the force F required to keep the small trolley immobile on the triangular trolley.



3. Force with friction

Carl tries to move a table of mass M, which has a pile of books sitting on it of total mass m. The dynamic coefficient of friction (between the table and floor) is μ_d and the static coefficient of friction (between the table and books) is μ_s. Determine the maximum force that Carl can apply to the table for which the books do not slide. Assume the books do not slide with respect to each other. Examine your result using the values $\mu_s = 0.75$, $\mu_d = 0.5$, $m = 3$ kg, and $M = 10$ kg.



4. Challenge: Rugby up-and-under play

A rugby technique called *up-and-under* consists of kicking the ball far and wide and then running under its path in order to catch it before it lands. The player can run with a maximum speed of v_p^{max} and can give the ball an initial maximum speed of v_{bi}^{max}. Assume the ball's trajectory is parabolic and that the player runs at a constant velocity starting the instant that the ball is in the air.

1. What angle with the ground α should she kick the ball at to maximize the distance at which she catches the ball (i.e. the distance between where the kick occurs and where the catch occurs)? What is this maximum distance?

2. Considering that the attacking player kicks the ball as described in part 1. How far should the defense be placed (from the opposing player) to counter her shot? The height of the defensive player's hand in the air is h.

5. Homework: Elevator

A person is standing in an elevator. Initially the elevator is at rest. The elevator then begins to ascend to the sixth floor, which is a distance h above the starting point. The elevator undergoes an unknown constant acceleration a for a time t_1. Then the elevator moves at a constant velocity for a time interval $\Delta t_2 = 4t_1$. Finally, the elevator brakes with a deceleration of the same magnitude as the initial acceleration for a time interval $\Delta t_3 = t_1$, until stopping at the sixth floor. Assume the gravitational constant is given as g. Find the magnitude of the acceleration.

1. Sketch the position, velocity, and acceleration as a function of time.

2. Briefly explain how you intend to model this problem and write down your strategy before solving it.

3. Use numbers from your everyday experience to estimate the height h and the time t_1 and check if your answer makes sense.