Physics 271, Sections H1 & H2 — Thursday, Sep 25, 2014
Problems #3 — Force & Motion [I]

1) You are holding N masses m which are suspended from a cord as shown in fig. 1. Gravity field is g, downward in the figure.

a) Find the tension in each part of the cord.
b) Find the tensions again, if you move the system up with an acceleration a.
c) Find the tensions again, if you move the system horizontally with an acceleration a.

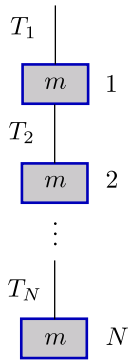

Figure 1: A cord with N masses attached to it.

2) Sailing
When sailing, there are multiple forces acting on the boat. We organize these forces as $\mathbf{F}_{\text{sail}}$, $\mathbf{F}_{\text{keel}}$, and $\mathbf{F}_{\text{drag}}$. For simplicity assume that the water is calm. In the boat's frame of reference, the velocity of the wind and water is as shown in the fig. 2. The mass of the boat is $m = 1.2 \times 10^3$ kg. We call the forward direction $\hat{\mathbf{y}}$ and the starboard direction $\hat{\mathbf{x}}$.

a) [fun] Explain all the forces. Use the concepts of the Newton's third law and $\mathbf{F} = \mathrm{d}\mathbf{P}/\mathrm{d}t$ for water and air. What are the limits of the sailing considering the wind angle?

In water's frame of reference, assume that $F_{\text{sail}} = 1.5 \times 10^4$ N with an angle $\theta_{\text{s}} = 30°$, $\theta_{\text{k}} = 10°$ and $\mathbf{F}_{\text{drag}} \cdot \hat{\mathbf{x}} = 0$. Find the forces F_{keel} and F_{drag} if:
b) the boat is going with a constant velocity. Say $\mathbf{v}_{\text{boat}} = (1.0\hat{\mathbf{x}} + 10\hat{\mathbf{y}})$ m/s in water's frame of reference.
c) the boat is going with velocity $\mathbf{v}_{\text{boat}}(t) = (0.1t\hat{\mathbf{x}} + 1.0t\hat{\mathbf{y}})$ m/s in water's frame of reference.
d) Use the values F_{keel} and F_{drag} that you have found in part 'b'. If we turn on the engine and add a force $\mathbf{F}_{\text{engine}} = 5\hat{\mathbf{y}}$ kN, find the acceleration of the boat right after starting the engine. The reason we talk about "right after starting the engine" is that the forces are velocity dependent.

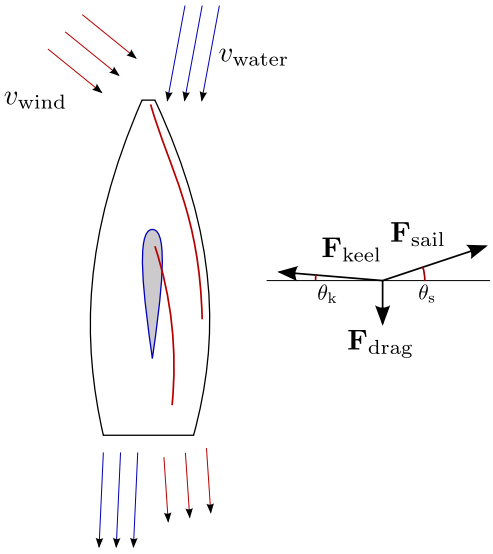

Figure 2: Sailing.

3) Consider a mass $m_1 = 5$ kg on a place inclined with an angle $\theta = \sin^{-1}(3/5)$, connected with a string over a pulley to a mass $M = 10$ kg on a horizontal plane, and M is connected to another mass m_2 hanging with a pulley. See fig. 3. All the friction forces are negligible.

a) Find m_2 so that the system is at equilibrium.
b) If $m_2 = 5$ kg, find the acceleration and the tension forces.

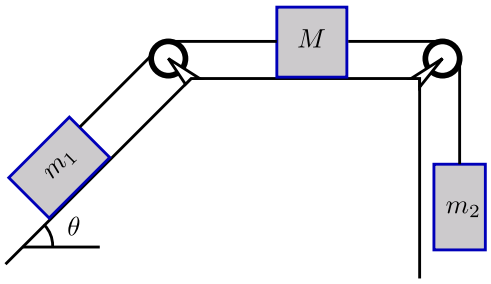

Figure 3: Three masses connected with two strings.