1.050: Checklist Exercises

Due: Wednesday – September 12, 2007 (In Class)

MIT – 1.050 (Engineering Mechanics I)
Fall 2007
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This subject, 1.050 Engineering Mechanics I, builds upon what you have learned in your physics and mathematics courses, in particular at MIT, 8.01 and 18.01. The following exercises, which are inspired from problem sets in 8.01 and 18.01, are designed for you to refresh your memory after the long summer. They are also important for us to get a good feel on what we can build together – now that we start to explore the world of Engineering Mechanics. In all these exercises, specify your assumptions, and feel free to add any physics quantity you may need to provide an engineering answer. Furthermore, specify all the resources you use for your solution.

Team Building and Team Work We strongly encourage you to form Homework teams of three students. Each team only submits one solution for correction. We expect true team work, i.e. one where everybody contributes equally to the result. This is testified by the team members signing at the end of the team copy a written declaration that "the undersigned have equally contributed to the homework". Ideally, each student will work first individually through the homework set. The team then meets and discusses questions, difficulties and solutions, and eventually, meet with TA or instructor. This first assignment is a good occasion for team building.

1. **A waiter's job:** A new waiter is given the task of holding a tray of size $5l$, with three drinks of various weights. The drinks are distributed in the tray as displayed in the figure. Calculate the location along the tray where the waiter should place his hand in order to lift and equilibrate all the items.

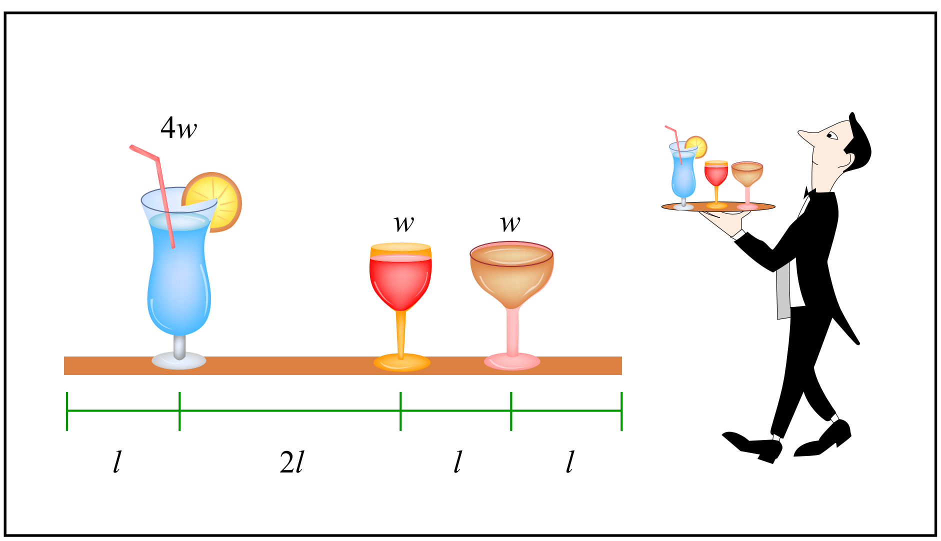
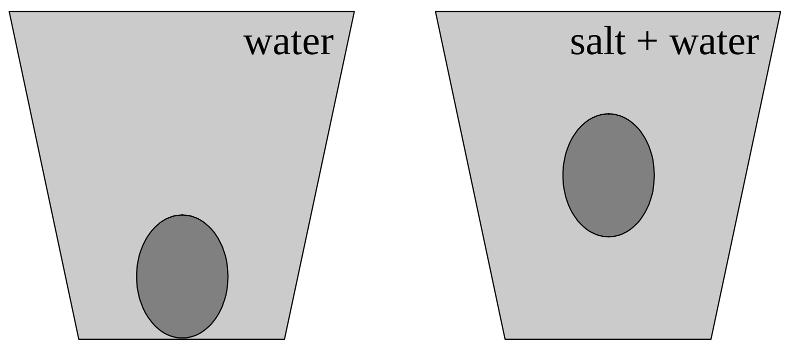


Figure by MIT OpenCourseWare.

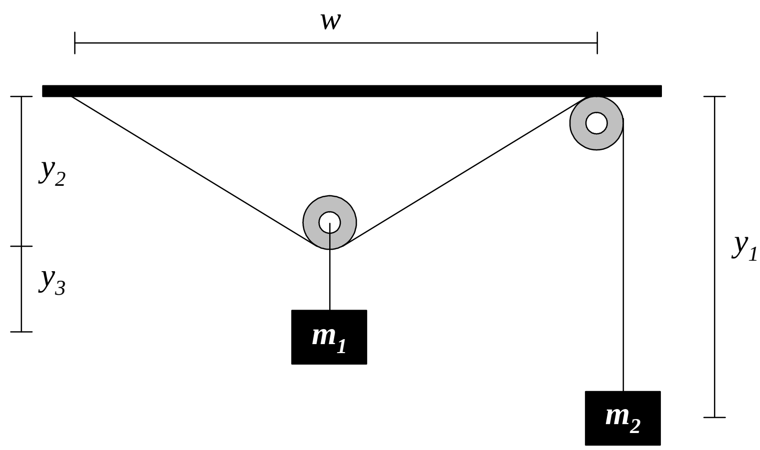
2. **The floating egg:**

   (a) When Alberto placed an egg in a container full of water, he noticed that it sank. Why was that so? Explain the phenomenon.

   (b) Someone told Alberto a trick to make the egg float: add some salt to the water, mix thoroughly, and surely enough, the egg floated! If the container Alberto used had 1 liter of water, how much salt did he add to make the egg float? Make any assumptions you think appropriate, just make sure to justify your procedure. Use the handout from the CRC Handbook of Chemistry and Physics posted in the class website for data on concentration of salt and mass per unit weight of water.



3. **Hanging from the ceiling:** A rope of length L is hanging from the ceiling. The left end of the rope is fixed to the ceiling. The right end is connected to a mass (m_2) after passing around a pulley. A second mass (m_1) hangs from the rope as shown in the figure. Both pulleys are frictionless. Find the position y_1, for which the system is at rest (Hint: use energy arguments).



4. **A drag force exercise:** From the top of a skyscraper, one decides to drop a ball with an initial velocity V_0. In a first approach, the drag force F_D due to air resistance can be approximated in the form,

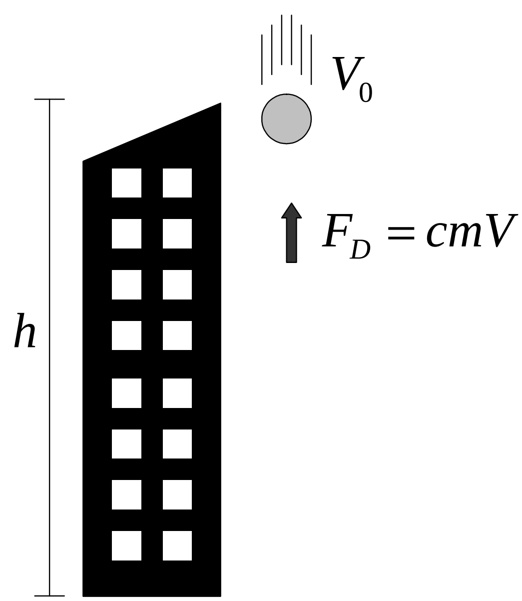
$$F_D = cmV$$

where c is the drag coefficient, m the mass of the object, and V the velocity.

(a) Set up the differential equation, and solve for the position of the ball as a function of time, $z(t)$. Use the appropriate boundary conditions.

(b) Calculate the terminal velocity for the motion of the ball. Assume that the height of the building and the time to reach the floor are large enough to allow the ball to reach the terminal velocity.

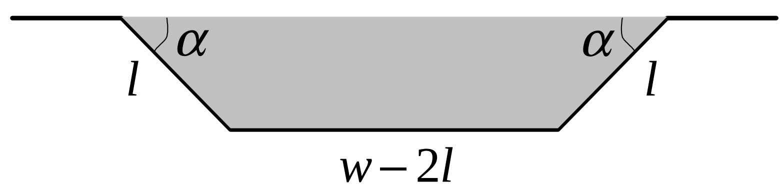
(c) *Numerical application:* Using a drag coefficient $c = 0.1\ \mathrm{s}^{-1}$, plot the velocity of the ball as a function of time $v(t)$ for three different initial velocities: $V_0 = 10, 100, 200$ m/s. For this numerical application, use MATLAB to construct the plot. Interpret your results.



5. **Building of a channel:** You have just been hired as an engineer to design a channel for water flow. The available material has a width w, and it is bent into three straight sections as observed in the figure. Your goal as the designer is to maximize the flow of water on the channel, which is directly proportional to the maximum cross-section area.

   (a) Find the optimal dimensions l and α for the channel displayed in the figure.

   (b) A colleague of yours in the company proposes the use of a semi-circular shape for the same size of cross-section area obtained in part (a). Would this be advantageous? Explain your answer in terms of other engineering aspects involved in optimization problems (e.g. material cost, labor).



6. **On vectors and more vectors**

   (a) **About a triangle:** Find the area of a triangle determined by two vectors: $\overrightarrow{n} = 4\overrightarrow{e}_1 + 7\overrightarrow{e}_3$ and $\overrightarrow{t} = 2\overrightarrow{e}_1 - 3\overrightarrow{e}_2 + \overrightarrow{e}_3$. Also, calculate the unit vectors that are normal (perpendicular) to the plane described by $\overrightarrow{n}$ and $\overrightarrow{t}$.

   (b) **World map:** Ecuador and Malaysia lie on the Equator (approximately). Ecuador is located $80^\circ\ W$ and Malaysia is located $110^\circ\ E$. Calculate the distance between the two countries:

      i. along the shortest route on the surface of our planet.

      ii. along a direct path going through (or inside) our planet.

   (c) **Dust particle:** A dust particle has the following motion as a function of time t,

$$\overrightarrow{r}(t) = \beta\left[1 - \cos(\alpha t)\right]\overrightarrow{e}_1 + \beta\left[\alpha t - \sin(\alpha t)\right]\overrightarrow{e}_2$$

   where α, β are constant coefficients.

      i. Determine the velocity and acceleration of the particle as functions of time.

      ii. For what values of time t is the dust particle at rest?

      iii. Calculate the angle formed by the velocity and acceleration vectors.