2.003J/1.053J Dynamics and Control I

Massachusetts Institute of Technology
Department of Mechanical Engineering
Fall 2010, Problem Set 1
Issued: September 9, 2010
Two online surveys due[1]: September 13, 2010, 11:59 PM
Problem set due: September 16, 2010, 9:30 AM

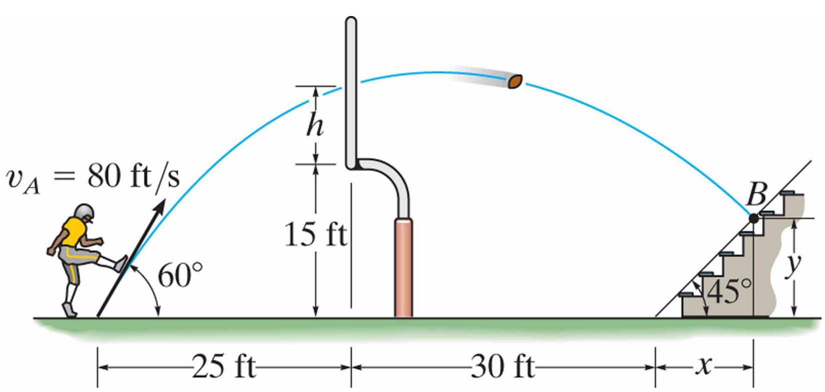
The online portion of this week's homework (the online surveys) is to be completed by midnight Monday (in future homework assignments, the surveys must be completed by midnight Saturday after they are assigned on Thursday). It accounts for 25% of the problem set grade. The problem set solutions are due at lecture: 9:30 AM September 16, 2010

At lecture there will be a box for each recitation. Put your solution into the box for your recitation. It will be returned to you at recitation on Thursday or Friday.

1. To receive credit for this first problem, you must post at least one comment on the pdf named pset1_prob1_due9-16-10, which is posted on the NB course page. To learn how to post comments, please see the NB tutorial posted on the Stellar course page (under Materials, under Tutorials). Please be sure to view the most recent version. Additional tutorials (though slightly outdated) provided by the makers of NB can also be found on the NB home page (http://nb.csail.mit.edu/). The guided video tour on the NB home page is informative.

2. This is a review problem on the topic of projectile motion. This material will not be covered in lecture but you are expected to be familiar with it. Read Sections 12.1, 12.2, 12.3 (skim) and 12.4–12.6 in the subject textbook "Engineering Mechanics: Dynamics" by Hibbeler. Do problem 12-104 in the text (also shown below). Show your method. A single word or number answer is not adequate.

   Problem 12-104: The football is kicked over the goalpost with an initial velocity of $v_a = 80$ ft/s as shown. Determine the point *B(x, y)* where it strikes the bleachers.



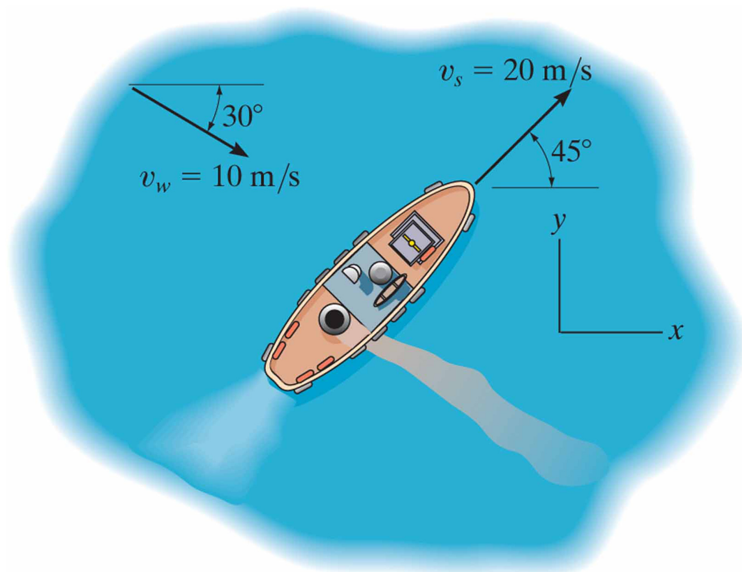
PROB12_104.jpg

3. Read section 12.10 in the text. Do problem 12-218 in the text. If you are not sure how to do it at first, try the simpler practice problem F12-46 first. It is not required, but it is a good introduction to the

[1] This week, you are required to complete two online surveys: one pertains to the technical material covered in class and the current problem set, and the other is a non-technical survey to help the teaching staff understand the student population. Weekly online surveys (as part of the homework grade) will typically be due on the Saturday night after they are assigned on Thursday. However, we will give you a couple more days to complete the surveys this first week.

basic technique. The answer to F12-46 is in the back of the text book.

Problem 12-218: The ship travels at a constant speed of $v_s = 20$ m/s and the wind is blowing at a speed of $v_w = 10$ m/s, as shown. Determine the magnitude and direction of the horizontal component of velocity of the smoke coming from the smoke stack as it appears to a passenger on the ship.



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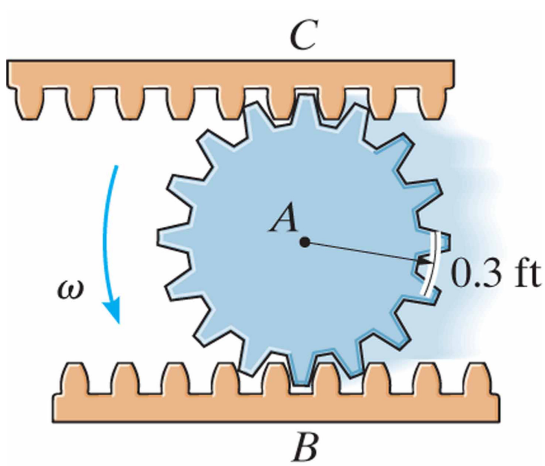
4. Read sections 16.5 and 16.6 and then do Problem 16-54 in the text.

   Problem 16-54: Pinion gear A rolls on the fixed gear rack B with an angular velocity $\omega = 4$ rad/s. Determine the velocity of the gear rack C.



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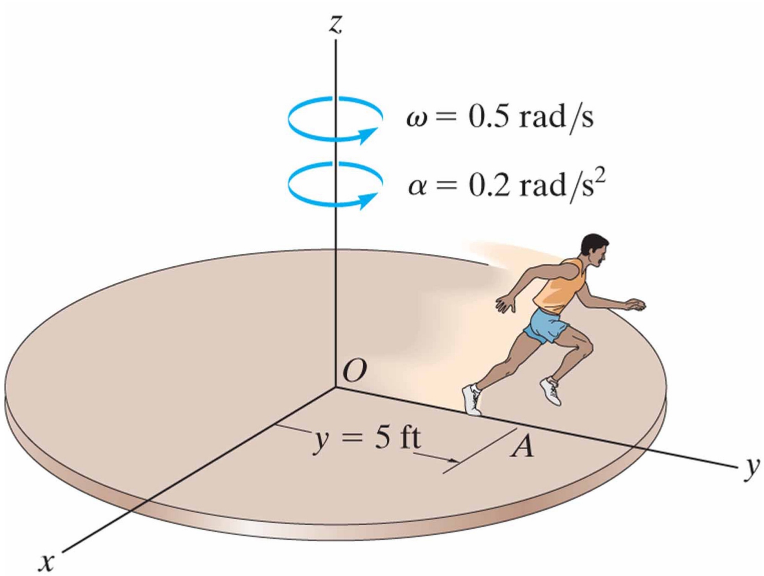
5. Read pages 377–379 in section 16.8, which is on the topic of the velocity of a point in a translating and rotating reference frame. Read problem 16-139. Compute *only* the velocity of the man as seen

from a reference frame fixed to the ground and not rotating with the platform. You need to specify the location and orientation of the coordinate system in the reference frame attached to the ground in relation to the coordinate system attached to the platform.

Problem 16-139: The man stands on the platform at O and runs out toward the edge such that when he is at A, $y = 5$ ft, his mass center has a velocity of 2 ft/s and an acceleration of 3 ft/s^2, both measured relative to the platform and directed along the positive y axis. If the platform has the angular motions show, determine the velocity of his mass center at this instant.



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6. Use vectors in computing the following parts of this problem

   (a) Find the center of mass $\mathbf{r}_{\mathrm{G/O}}$ of several particles in Cartesian coordinates in Figure 1. Let $m_1 = 3m$, $\mathbf{r}_{1/O} = (2;\ 2;\ 5)$,$m_2 = m$, $\mathbf{r}_{2/O} = (-2; 4; 3)$, $m_3 = 5m$, $\mathbf{r}_{3/O} = (4; 0; 2)$, $\mathbf{v}_{1/O} = (1; -4; 3)v$, $\mathbf{v}_{2/O} = (1; 0; 0)v$, and $\mathbf{v}_{3/O} = (-2; -1; -1)v$, where $m = 1.0$ kg and $v = 10$ m/s. The position vectors have units of meters.

   (b) Let $\mathbf{v}_{i/O} = \dot{\mathbf{r}}_{i/O}$. Compute the total linear momentum P of the particles with respect to the O_{xyz} reference frame and compute the velocity of the center of mass, $\dot{\mathbf{r}}_{G/O} = v_{G/O}$.

   (c) Find the total kinetic energy of the group of particles, and determine if

$$\frac{1}{2}M_T v_{G/O} \cdot v_{G/O} = \sum_i \frac{1}{2} m_i v_{i/O} \cdot v_{i/O}$$

   where $M_T = \sum m_i$.

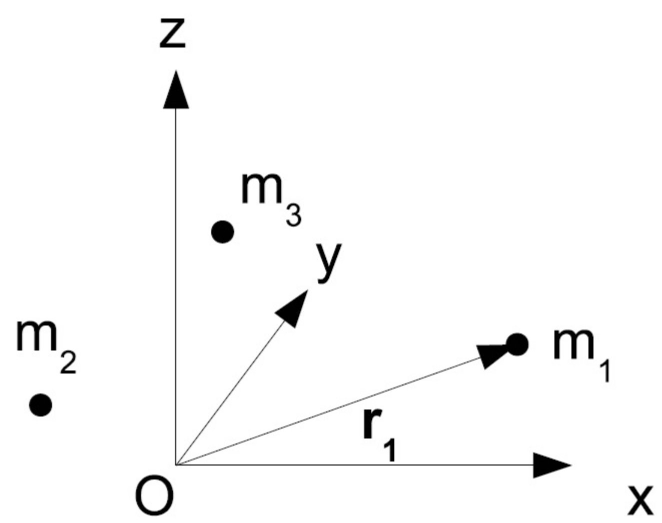

Figure 1: Three particles in an O_{xyz} Cartesian coordinate frame.

7. In a fixed inertial frame O_{xyz}, two cars approach one another at equal but opposite velocities (see Figure 2). Call them cars 1 and 2 with masses m_1 and m_2, respectively. Let $\mathbf{v}_{1/O} = 25\mathbf{i}$ m/s, $\mathbf{v}_{2/O} = 25\mathbf{i}$ m/s, $m_1 = 1000$ kg, and $m_2 = 2000$ kg.

   (a) The two cars collide head on and stick together. Assume they behave as particles and ignore friction with the road. Compute the total linear momentum and total kinetic energy before and after the collision. In other words, compute $\mathbf{P}_1$ and $\mathbf{P}_2$, before and after, T_1 and T_2, before and after, as seen by an observer at O_{xyz}. Compute$(\triangle \mathbf{P})_O = (\mathbf{P}_1 + \mathbf{P}_2)_{after-}(\mathbf{P}_1 + \mathbf{P}_2)_{before}$ and $(\triangle T)_O = (T_1 + T_2)_{after} - (T_1 + T_2)_{before}$.

   (b) You are riding in a train running parallel to the road with velocity the same as vehicle 1, $\mathbf{v}_{train/O} = \mathbf{v}_{1/O} = 25\mathbf{i}_O$ m/s . The train is not accelerating and thus you are in an inertial reference frame.

      i. Then, like before, compute $(\triangle \mathbf{P})_{O'} = (\mathbf{P}_1 + \mathbf{P}_2)_{after-}(\mathbf{P}_1 + \mathbf{P}_2)_{before}$ and $(\triangle T)_{O'} = (T_1 + T_2)_{after} - (T_1 + T_2)_{before}$ in terms of the velocities observed from the train.

      ii. Was your intuition correct? Summarize your conclusions regarding changes in linear momentum and kinetic energy in collisions when viewed in two dierent inertial reference frames traveling at dierent velocities.

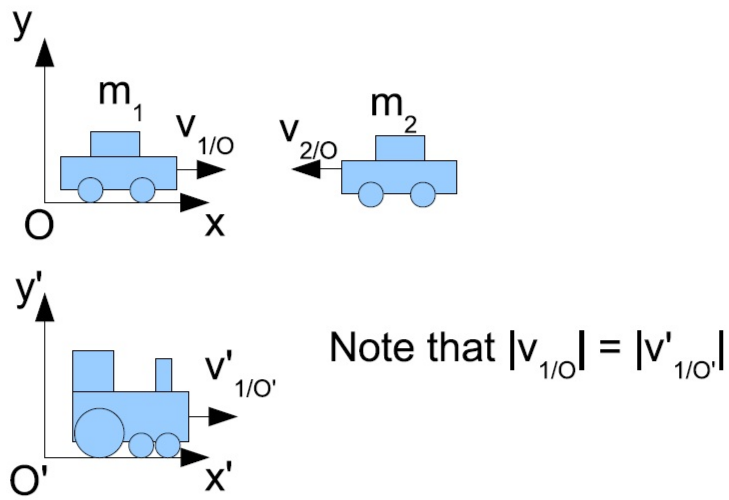

Figure 2: Two cars collide and stick together.

8. This is a question intended to test your knowledge acquired prior to taking this subject. It is not really covered in the lecture or readings in the subject to this point. Do the best you can with it. For the mass-spring-dashpot system on a slope as shown in Figure 3 assume that motion is allowed only parallel to the page and up/down the slope. The angle of the slope is θ, and there is a friction coefficient μ.

   (a) Draw a free body diagram.

   (b) Assign appropriate coordinates.

   (c) Find an equation of motion for the mass on the incline.

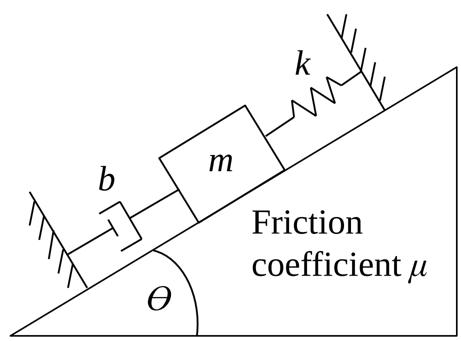

Figure 3: Mass-spring-dashpot system