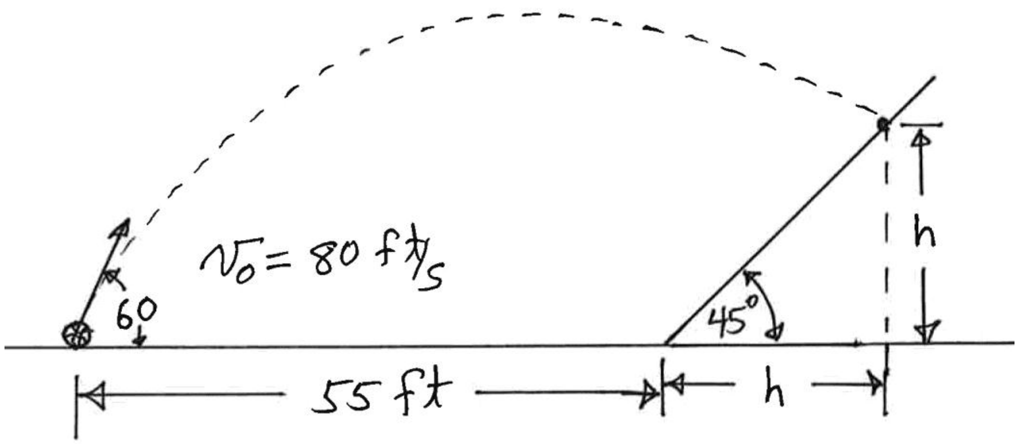
2.003SC Engineering Dynamics

Problem Set 1

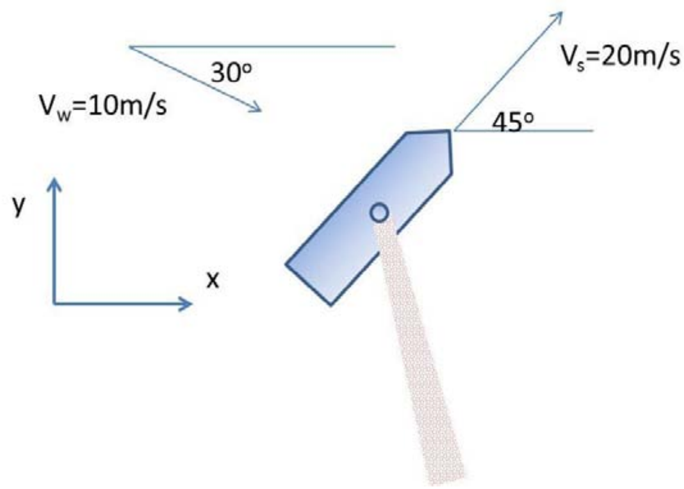
1. This is a review problem on the topic of projectile motion. A football player kicks a ball, giving it an initial speed of 80 ft/s with an initial angle relative to the horizontal of 60 degrees. The distance to the foot of the stands is 55 feet. Will the ball leave the playing field, and if so, where will it land in the stands? The stands have a slope of 45 degrees. The unknown horizontal and vertical distance which locates the point the ball lands in the stands is designated as 'h'. Find 'h'. To simplify this problem, assume that there is no air resistance. Before attempting to solve the problem. Do the concept question given below.



Concept Question 1: What is the magnitude of the horizontal component of football's velocity at the top of the arc? A. 80 ft/s, B. 40 ft/s, C. $40\sqrt{3}\ ft/s$.

The purpose of concept questions is to test your previous knowledge and to see if your initial intuition will start you off on the right path to solving the problem. It is recommended that before you begin each problem you answer the concept question. Then look up the answer to the concept, which is provided at the bottom of the page for each week. If your answer to the concept question is incorrect, it is likely that you may start down an unproductive pathway to a solution. Try to fully understand the answer to the concept question before you begin the regular problem.

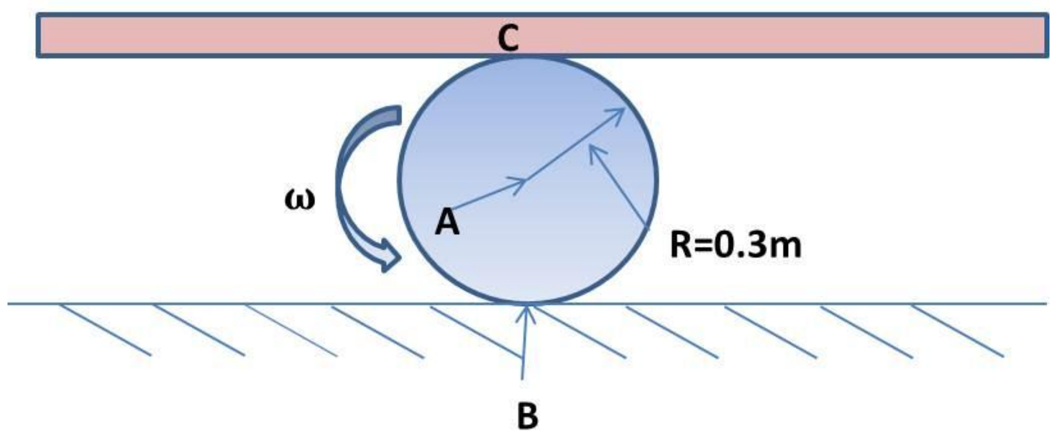
2. The ship in the diagram travels at a constant speed of V_s=20m/s. The wind is blowing at a speed of V_w=10 m/s, with directions as shown in the figure. Determine the magnitude and direction of the smoke coming from the smokestack as it appears to a passenger on the ship. It is strongly recommended that you use vectors to solve this problem, so as to warm up for more difficult vector-based problems soon to follow.



Concept Question 2: For the conditions described in this problem, is the reference frame of the ship an inertial frame.

A. Yes, B. No, C. Do not know.

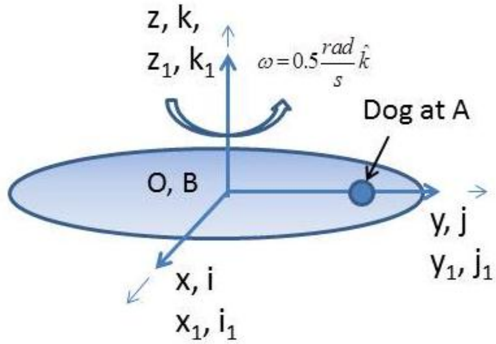
3. A wheel with center at A rolls without slipping at B on a non-moving surface. The wheel rolls with an angular velocity of 4 radians/second in the direction shown in the figure. A rigid bar is supported by the wheel and moves horizontally without slipping due to its contact with the wheel. Determine the velocity of the moving bar at its point of contact with the wheel at C.



Concept Question 3: Where is the instantaneous center of rotation of the wheel in this problem?
A. The center of the wheel at point A,
B. The point of contact between the wheel and the ground, B, or
C. The point of contact between the wheel and the moving bar at C.

4. A dog runs radially outward on a rotating platform. Compute the velocity of the dog as seen from a reference frame O_{xyz} fixed to the ground and not rotating with the platform. In the figure coordinate system B_{x1y1z1} is attached to the platform. In the B_{x1y1z1} frame the

dog has a velocity of +2 ft/s, measured relative to the platform and directed radially outward along the positive y_1 axis. If the platform has an angular velocity of 0.5 radians/second in the +**k** direction, determine the velocity of the dog's center of mass at the instant shown, as observed from the fixed inertial frame. At the instant shown the rotating and fixed coordinate systems align.



Concept Question 4: Is the vector velocity of the dog on the platform, as observed from a fixed point in a reference frame attached to the ground, a function of the location of the fixed reference point.

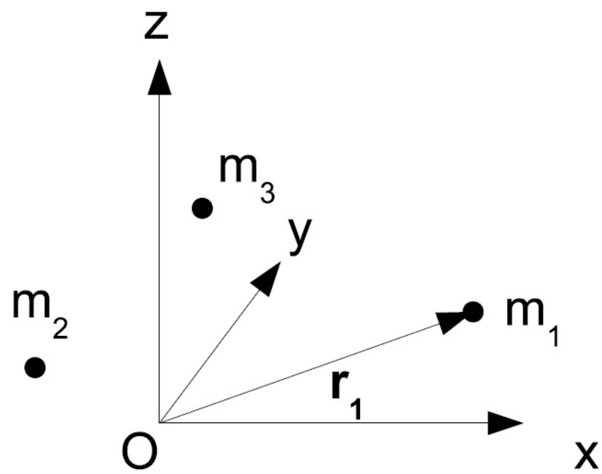
A. Yes,

B. No,

C. Do not know.

5. The reference frame, $O_{xyz,}$ shown in the figure is an inertial frame. In the figure, there are three particles, m_1=3m, m_2=m, and m_3=5m, where m = 1 kg. The xyz coordinates of the three masses are, respectively in meters, (2, 2, 5), (-2, 4, 3), and (4, 0, 2) in the reference frame shown. The three masses have the following velocity vectors: V_1=(1i, -4j, 3k)V_o, V_2=(1i, 0, 0)V_o, and V_3=(-2i, -1j, -1k)V_o, where V_o=10.0 m/s. The unit vectors associated with the x, y, and z directions are i, j, and k, respectively.

   a. Find the center of mass of the three particles in the reference frame shown.
   b. Compute the total linear momentum, **P,** of the three particles.
   c. Compute $V_{G/O,}$ the velocity of the center of mass of the three particles
   d. Compute $T_{total,}$ the total kinetic energy of the three particles.



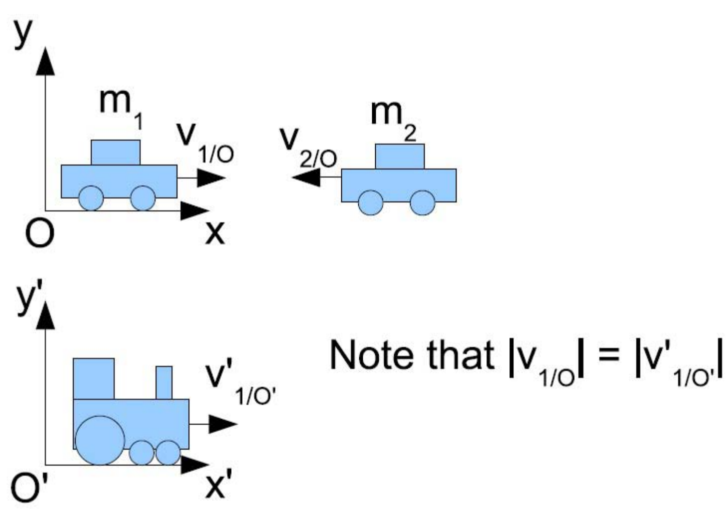
Concept Question 5: If you computed the total kinetic energy of the system using the total mass of the particles and the velocity of the center of mass, would the answer be:

A. less than,
B. greater than, or
C. equal to the sum of the kinetic energies of the particles taken individually as in part 'd' above?

6. Two cars approach one another at equal but opposite velocities as seen from a fixed inertial frame O_{xyz}. The two cars have masses and velocities given as: m_1=1000 kg, m_2=2000 kg, $V_{1/0}$ = 25**i** m/s, $V_{2/0}$= - 25**i** m/s. The two cars collide head on and stick together. Assume they behave as particles and ignore friction with the road.

    a. Compute the change in the total linear momentum of the two body system and the change in the total kinetic energy of the system before and after the collision.

    b. You are riding in a train running parallel to the road with the same velocity as the vehicle m_1. The train is not accelerating. Using a reference frame attached to the train, repeat the computation done in part 'a'. After obtaining an snswer, make up a rule that will generalize your result to the most general situation possible.



Concept Question 6: Do you expect the change in total momentum and total kinetic energy to be the same or different when viewed from two inertial frames traveling at different velocities?

7. This question is intended to test your knowledge acquired prior to taking this subject. All of the knowledge required to do this problem will be covered in this subject. Do the best you can with the problem.

   For the mass-spring-dashpot system on a slope as shown in the figure assume that motion is allowed only parallel to the page and up/down the slope. 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.

   Concept Question 7: Do you expect the undamped natural frequency of the system to be dependent on the angle of the incline?