Momentum

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Introduction

The following problems are about momentum, center of mass, or can be solved using estimation techniques. The first question is worth 1 point, the second question is worth 2 points, and so on. Work in groups and aim for the highest number of points. Have fun!

Key Ideas

- Momentum: $p = mv$
- Conservation of Momentum (only in closed systems): $\sum p_i = \sum p_f$
- Impulse: $J = \Delta p = m\Delta v = F_{\text{avg}}\Delta t$
- Inelastic collisions: kinetic energy is not conserved
- Elastic collisions: $v_{1i} + v_{1f} = v_{2i} + v_{2f}$
- x-coordinate of center of mass: $x_{\text{CM}} = \frac{\sum m_i x_i}{M}$

Problems

1. If I combine all of the liquid I will drink over my lifetime, how many baths would it fill?

2. (2018 $F = ma$) A 3.0 kg mass moving at 30 m/s to the right collides elastically with a 2.0 kg mass traveling at 20 m/s to the left. After the collision, the center of mass of the system is moving at a speed of
   a) 5 m/s
   b) 10 m/s
   c) 20 m/s
   d) 24 m/s
   e) 26 m/s

3. (2018 $F = ma$) A basketball is released from rest and bounces on the ground. Considering only the ball just before and just after the bounce, which of the following statements must be true?
   a) The momentum and the total energy of the ball are conserved.
   b) The momentum of the ball is conserved, but not the kinetic energy.

c) The total energy of the ball is conserved, but not the momentum.

d) The kinetic energy of the ball is conserved, but not the momentum.

e) Neither the kinetic energy of the ball nor the momentum is conserved.

4. N balls with mass m lie at rest in a line on a frictionless table, with a small separation between adjacent balls. The first ball is given a kick and acquires a speed v. It collides and sticks to the second ball, and the resulting blob collides and sticks to the third ball, and so on. What is the final speed of the resulting blob of mass Nm?

5. (2013 $F = ma$) A cart of mass m moving at 12 m/s to the right collides elastically with a cart of mass 4.0 kg that is originally at rest. After the collision, the cart of mass m moves to the left with a velocity of 6.0 m/s. Assuming an elastic collision in one dimension only, what is the velocity of the center of mass (v/cm) of the two carts before the collision?

   a) 2 cm/s

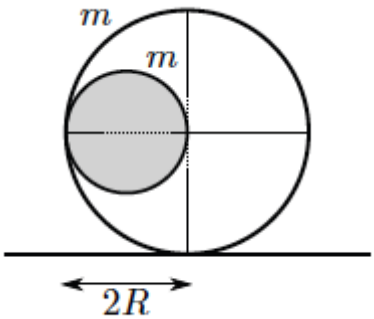
   b) 3 cm/s

   c) 6 cm/s

   d) 9 cm/s

   e) 18 cm/s

6. (2017 $F = ma$) A ball of radius R and mass m is magically put inside a thin shell of the same mass and radius 2R. The system is at rest on a horizontal frictionless surface initially. When the ball is, again magically, released inside the shell, it sloshes around in the shell and eventually stops at the bottom of the shell. How far does the shell move from its initial contact point with the surface?



   a) R

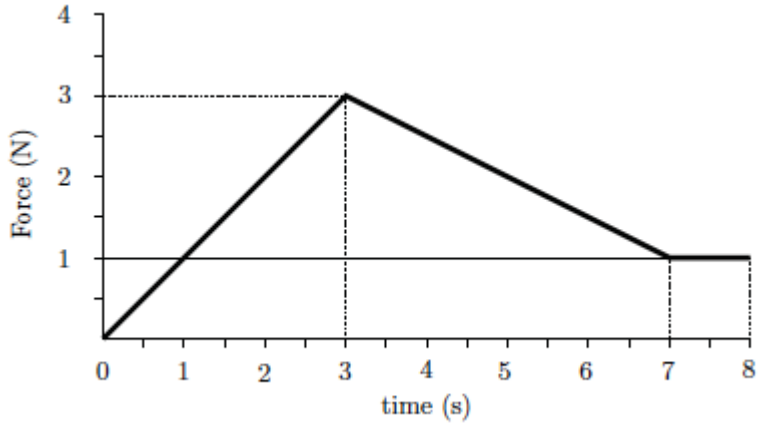
   b) $R/2$

   c) $R/4$

   d) $3R/8$

   e) $R/8$

7. (2014 $F = ma$) A 5.0 kg object undergoes a time-varying force as shown in the graph below. If the velocity at $t = 0.0$ s is $+1.0$ m/s, what is the velocity of the object at $t = 7$ s?



a) 2.45 m/s

b) 2.50 m/s

c) 3.50 m/s

d) 12.5 m/s

e) 15.0 m/s

Answers

1. 113
2. b
3. e
4. $v_f = v/N$
5. b
6. b
7. c