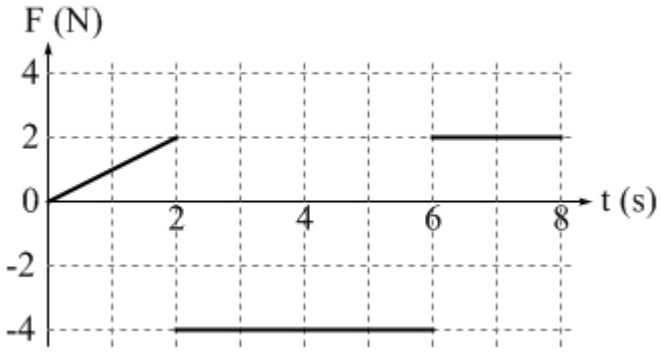
PROBLEM 1 – 10 points

At $t = 0$, an object of mass 0.50 kg is passing through the origin with a velocity of 8.0 m/s in the positive x direction. It is then subjected to a net force in the x-direction that varies in magnitude and direction as shown by the graph.



When the force is positive it means the force is directed in the $+x$ direction. When the force is negative it is directed in the $-x$ direction.

[4 points] (a) What is the object's velocity at $t = 8$ s?

[3 points] (b) When does the object reach its maximum speed? Justify your answer.

[3 points] (c) What is the maximum speed reached by the object?

PROBLEM 2 – 10 points

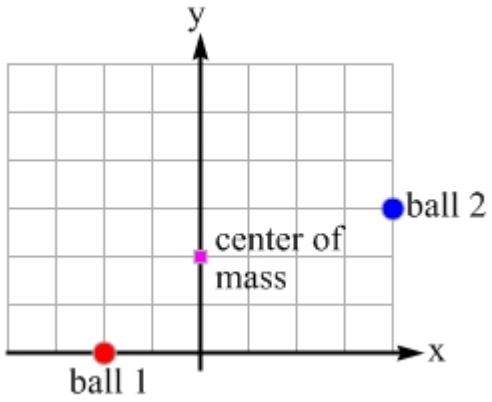
A 60 kg man and his 40 kg dog are sitting together at the left end of a boat that is 8.0 m long. The boat's mass is 100 kg, and we can assume the boat's center of mass is in the center of the boat. The boat starts out at rest in the middle of a calm lake. Ignore all friction and water resistance throughout this problem.

[3 points] (a) Where is the center of mass of the boat + man + dog system? Indicate your answer by stating the distance from the man to the center of mass of the system.

[4 points] (b) Suppose that the dog moves to the other end of the boat, while the man stays still. How far does the boat move as a result? Indicate the magnitude as well as the direction (to the left or to the right) of the boat's displacement.

[3 points] (c) After reaching the other end of the boat, the dog jumps off with a horizontal velocity of 2.0 m/s, directed to the right, as measured relative to the water. What is the speed with which the boat and the man drift in the opposite direction?

PROBLEM 3 – 15 points



A system consists of three balls at different locations near the origin, as shown at right. Ball 1 has a mass of 2.0 kg and is located on the x-axis at $x_1 = -2.0$ m; ball 2 has an unknown mass and is located at ($x_2 = +4.0$ m, $y_2 = +3.0$ m); ball 3 is somewhere on the y-axis at an unknown location, and it has a mass of 1.0 kg.

The coordinates of the center-of-mass of this system are ($x_{CM} = 0$, $y_{CM} = +2.0$ m). The squares on the grid measure 1.0 m × 1.0 m.

[4 points] (a) Calculate the mass of ball 2.

[4 points] (b) Find the location of ball 3.

[3 points] (c) Let's say you can set the mass of ball 3 to be any non-negative value. By adjusting the mass of ball 3, what range of positions can the center-of-mass of this system occupy?

[4 points] (d) Return to the original situation, with the center-of-mass of the system at ($x_{CM} = 0$, $y_{CM} = +2.0$ m). You now adjust the mass of one of the balls, and you observe that this adjustment causes the center of mass of the system to shift a little to the right and a little higher than $y = +2.0$ m. Which of the following changes could have caused this? **Select all that apply**.

[ ] the mass of ball 1 was increased

[ ] the mass of ball 1 was decreased

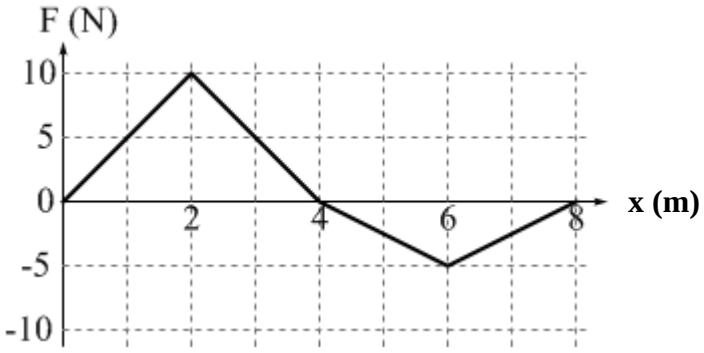
[ ] the mass of ball 2 was increased

[ ] the mass of ball 2 was decreased

[ ] the mass of ball 3 was increased

[ ] the mass of ball 3 was decreased

PROBLEM 4 – 20 points



When an object with a mass of 2.0 kg passes through the origin, its velocity is 4.0 m/s in the positive *x*-direction. It is then subjected to a net force in the *x*-direction that varies in magnitude and direction as shown by the graph. Note that the graph gives force as a function of position, not force as a function of time.

When the force is positive it means the force is directed in the +*x* direction. When the force is negative it is directed in the –*x* direction.

[4 points] (a) At what location does the object reach its maximum speed? Justify your answer.

[6 points] (b) What is the maximum speed reached by the object?

[5 points] (c) What is the object's kinetic energy when it reaches $x = +8$ m?

[5 points] (d) Now suppose the object started at $x = +6$ m instead of at $x = 0$. What minimum kinetic energy would the object need to have at $x = +6$ m to be able to make it to $x = 0$, assuming that its initial velocity was in the negative *x*-direction?