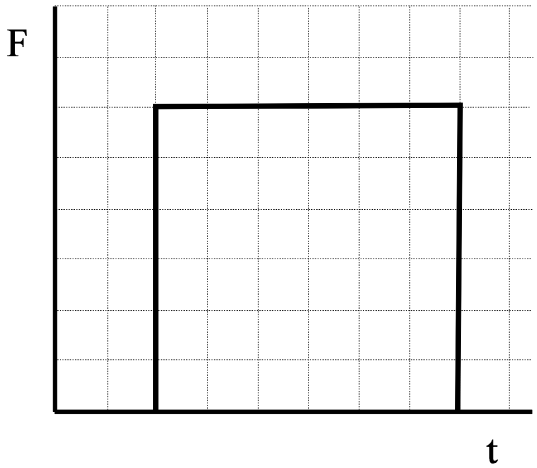
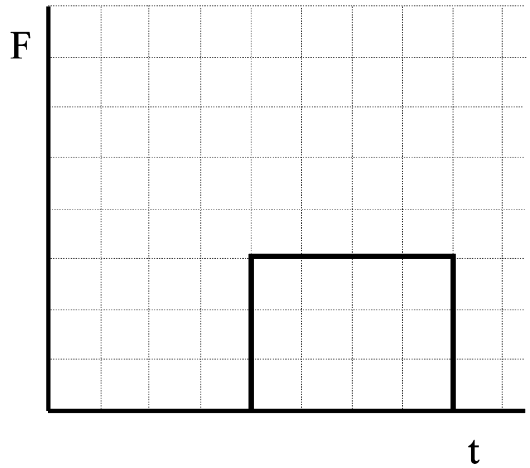
First Name:____________________ Last Name:______________________________

1. You have two objects with identical mass and each has a velocity $\vec{v} = -5\,\hat{x}$ m/s. One of those objects is subjected to the force shown in the graph on the left. A positive force implies a force in the $+\hat{x}$ direction. As a result of that force, the object ends up with a velocity $\vec{v} = 25\,\hat{x}$ m/s. If the second object were subjected to the force shown in the graph on the right, what would its final velocity be? Explain your reasoning. Hint: think about impulse.

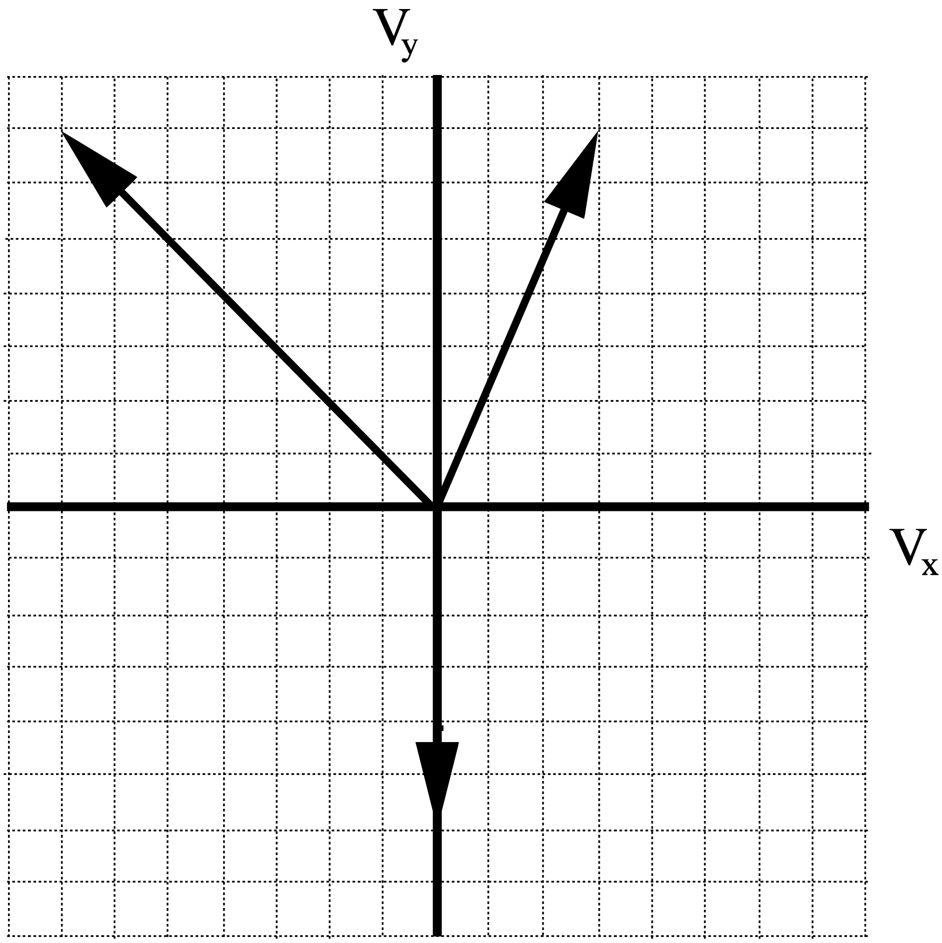


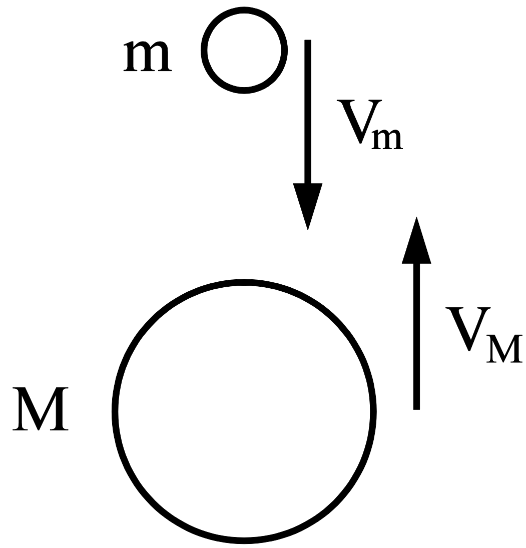


Contact: (Drew) milsom@email.arizona.edu

2. A mass $5M$ which is initially at rest breaks into four pieces; three have mass $M$ and one has mass $2M$. The figure shows the *velocity* vectors for the three mass $M$ pieces. Accurately draw in the velocity vector for the mass $2M$ piece. Show your reasoning and/or calculations.



A basketball and a tennis ball are about to collide as shown. A learning assistant can demonstrate a collision like this for you. The basketball has mass $M$ and the tennis ball has mass $m = \frac{M}{10}$. An instant before they collide, they each have the same speed so $V_M = V_m = 5$ m/s.




3. During the collision, the basketball and tennis ball certainly exert forces on each other. Which force is larger or are they the same size? Explain your reasoning.

4. As a result of that force, does each ball experience the same magnitude of acceleration or are they different? If they are different, by what factor are they different and which is larger? Explain your reasoning.

5. When this experiment is performed in your class, you measure the velocity of the basketball immediately after the collision to be 3.5 m/s upwards. Use the conservation of linear momentum to determine the velocity of the tennis ball immediately after the collision.

6. Determine the impulse given to each ball as a result of the collision. Compare those answers. Are they consistent with what you know about collisions? Explain. You may use $M = 1$ kg for this question.

7. Determine the change in velocity for each ball as a result of the collision. Compare those answers. Are they consistent with what you know about collisions? Explain. You may use $M = 1$ kg for this question.

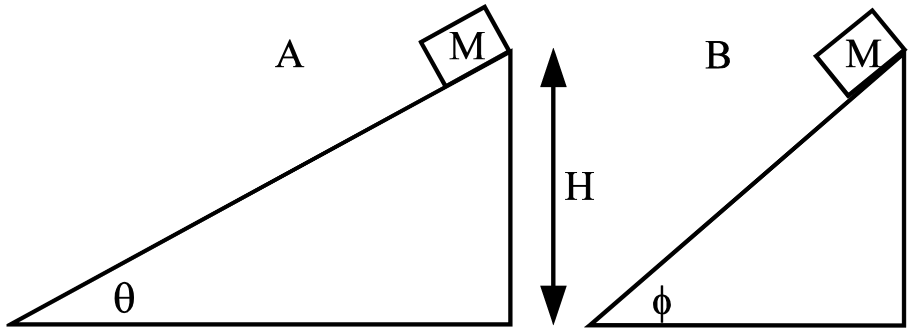
8. Determine the change in kinetic energy for each ball as a result of the collision. Compare those answers. Are they consistent with what you know about collisions? What type of collision is this? Explain. You may use $M = 1$ kg for this question.


Contact: (Drew) milsom@email.arizona.edu

9. Determine the ratio of the final kinetic energy of the system (consisting of both balls) to the initial kinetic energy of the system. You will certainly get a number less than 1.0. Explain what happened to the energy. (Note that you do not need the mass to calculate this.)


Contact: (Drew) milsom@email.arizona.edu

Identical blocks slide down two different inclines as shown. The inclines have the same height but are at different angles. Each incline is frictionless and each block is released from rest.




10. In which case is the speed of the block larger when it gets to the bottom of the incline or are they the same size? Explain your reasoning.

11. Is the linear momentum of each block at the bottom of the incline the same? Explain why or why not. (If you think it matters, you may assume that each block is at the very bottom of the incline and has not yet reached the horizontal surface.)

12. In which case is the magnitude of the linear momentum at the bottom of the incline larger or are they the same size? Explain your reasoning.


Contact: (Drew) milsom@email.arizona.edu

13. In which case is the magnitude of the impulse given to the block during this process larger or are they the same size? Explain your reasoning.

14. In which case is the net force acting on the block during this process larger or are they the same size? Explain your reasoning.

15. In which case is the time it takes to reach the bottom longer or do they take the same time? Explain your reasoning.

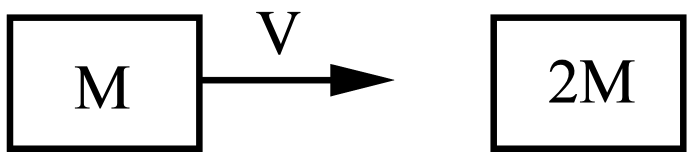
16. Are your answers to Questions #14-15 consistent with your answer to Question #13? Explain why or why not.


Contact: (Drew) milsom@email.arizona.edu

17. Determine the impulse using $\Delta\vec{p} = \vec{F}_{\text{net}}\Delta t$ and explicitly verify that $|\Delta\vec{p}|$ is the same for each case.


Contact: (Drew) milsom@email.arizona.edu

A mass M traveling at speed *V* is about to undergo a perfectly inelastic one-dimensional collision with a mass 2M which is initially stationary.




18. Determine the velocity of the masses after the collision.

19. Determine the ratio of the final kinetic energy to the initial kinetic energy. Given that this is a perfectly inelastic collision, we expect to lose as much energy as is physically possible.

**Let's now analyze this collision in the center of mass frame. In this frame, we will be able to prove that we are losing the most energy possible.**

20. Determine the center of mass velocity of this system.


Contact: (Drew) milsom@email.arizona.edu

21. Now let's view the collision in the center of mass frame. Imagine that you are moving to the right at the velocity you calculated in Question #20 so that the center of mass of the system is stationary from your perspective. What will be the initial velocity of **each** mass in this frame? Explain your reasoning and draw the collision as you will see it happen.

22. Determine the initial kinetic energy of the system as viewed in this frame. Hint: it will not be the same as you calculated in Question #19 since kinetic energy is frame dependent.

23. What is the velocity of the combined object after the collision as viewed in this frame? And what is its kinetic energy? Has this proven to you that you lose the most energy possible when the objects stick together? Explain your reasoning.


Contact: (Drew) milsom@email.arizona.edu

**Comments about this Tutorial:**

This has been used in both algebra-based and calculus-based physics courses.

This tutorial is really five separate activities (Questions #1, #2, #3-9, #10-17 and #18-23). Faculty should certainly consider Xeroxing these five activities in whatever order you find most appropriate.

Question #1 certainly focuses on understanding what impulse is. This can take 15 minutes. Many students will find the particle's mass along the way although you certainly don't need to. I would prefer that they just use proportional reasoning skills but they certainly still need to develop these better. If they assume that the area of each box in the graph is 1 Ns, then the mass is 1.2 kg.

On Question #2 some students certainly forget the mass difference.

Questions #3-9 are clearly related to the typical class demonstration. We definitely had the TAs/preceptors demonstrate this. Note that Questions #6-8 all have the question "Are they consistent with what you know about collisions?" This has been rephrased a couple of times in response to survey results. This seems to work better than the previous versions. The hope is certainly that students realize that the linear momentum is conserved in the collision but that the energy is expected to decrease.

Questions #10-17 also connect with work and energy and kinematics and also emphasize that linear momentum is a vector. A large percentage of students get Question #10 wrong. They don't want to go back to the energy conservation ideas they just learned in the previous chapter. They tend to try and use linear momentum somehow. So the preceptors may have to hint that they should try and use something they learned in a previous chapter.

Questions #18-23: I did have some students get completely through this packet during a summer session calculus-based physics course. However, it is very small number of people who have done this so I don't have any specific comments. This set of questions goes into some details many faculty may not care about but I think it is reasonable to cover this in an honors class.

In 50 minutes, most students get to about Questions #6-8 (the first two questions take a fair bit of time).

**Changes made in 2017:**

Question #8 now asks them to identify the type of collision.


Contact: (Drew) milsom@email.arizona.edu

**Tutorial Source(s):**

All Questions were written by Drew Milsom.


Contact: (Drew) milsom@email.arizona.edu