Physics Invention Sequences Users' Guide: Momentum

MOMENTUM INVENTION SEQUENCE

Includes: *danger index (product quantity), bumper absorption index (change in momentum), explosion/collision rule (conservation of momentum)*

Teacher Notes: Some instructors treat momentum before energy, so this may be the students first encounter with a product quantity. The Danger Index can serve as an everyday example, or as an introduction if momentum is the first product quantity. This sequence can be long. The first two prepare the students to learn about momentum, and the last task is more sophisticated. It represents an escalation in our expectations of student reasoning.

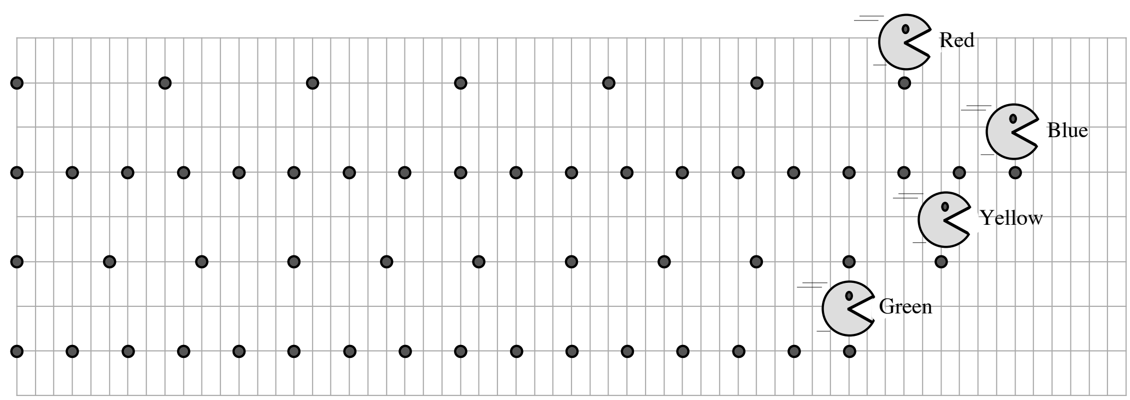
Levels: This sequence are appropriate for all levels, from middle school physical science through calculus-based physics.

Danger Index

You are playing a modified version of Pac-Man called Color-Pac.
The game involves the usual Pac-Man characters, which have different colors that represent their strength:

Color	Strength (powerpoints)
Blue	16
Yellow	10
Green	6
Red	6

The pac-men colors also correspond to different speeds. They all drop dots at the same rate, which allows comparison of how fast they are moving.



In this game, two pac-men face off in a battle. Great speed and high powerpoints are both important in deciding who will win in a battle. This means that for pac-men with the same speed, the one with most powerpoints will win; similarly, for pac-men with the same powerpoints, the faster one will win.

Your job is to invent a *danger index* to describe the pac-men above that will predict who wins in any battle - the pac-man with the highest danger index wins the battle. The rules are:

- The index should indicate who will win in a battle.
- You can invent new units through division and multiplication, but not through subtraction or addition.

Bumper Absorption Index

You are an automotive engineer designing bumpers for cars. The bumpers protect the car during collisions. A bumper is tested by putting it on a specific car that has a certain weight. The maximum speed at which a collision is safe is then measured by driving the car into a wall on a test track. Below are the results of some tests.

Invent an index to describe the bumpers. There are only a few types of bumpers. Determine which cars are using the same bumpers.

- The index should indicate how safe the bumper is, so bigger is better.
- You can invent new units through multiplication or division, but avoid subtraction and addition.

Trial car	Max safe speed (mph)	Car weight (lbs)
Honda	90	2000
Ford	50	3000
Jeep	40	5500
Subaru	55	4000
Toyota	60	2500
Acura	40	4500

Follow up questions

1. You make up a new, purple pac-man whose strength is 14. What speed could it have in order to come in second?
2. Suppose that the red pac-man was twice as fast as shown in the diagram. What strength would it need to maintain the same ranking?
3. Which cars had the same bumper?
4. Suppose the bumper that was tested on the Honda was placed on the Ford. What would the maximum safe collision speed be?

Collision/Explosion Rule

1. The initial and final states for four different events are shown below. Which ones are possible in an isolated system and which are not? Explain your reasons for saying one or more of the processes are impossible. The numbers indicate the relative mass and the relative speed of the blocks.

Initial state | Final state

(a)

Explain your reasoning:

(b)

Explain your reasoning:

(c)

Explain your reasoning:

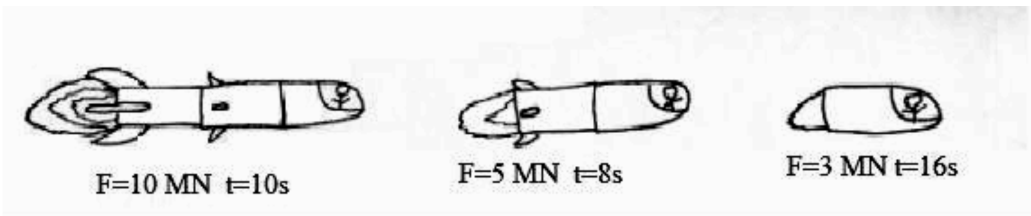
(d)

Explain your reasoning:

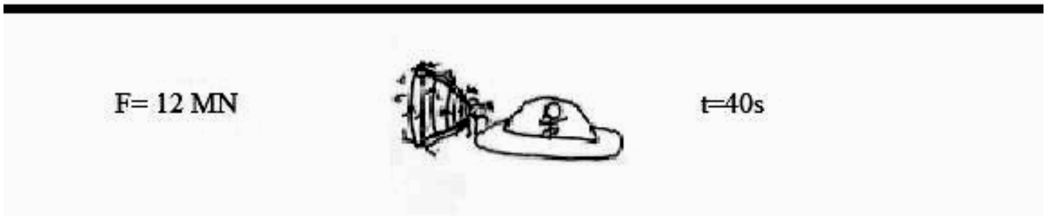
Rocket Boost Index

Rocket companies are competing to have their model selected for the next launch! As head propulsion engineer, you know you will need a lot of engine power for this project. The problem is even tougher because some rockets have multiple stages. The applicants and their engine stats are below; how can you quantify which engine will give your payload the biggest boost to get it into a proper orbit?
Invent a rocket boost index to help you decide which rocket is best suited to this launch. Remember – a higher index means more boost.

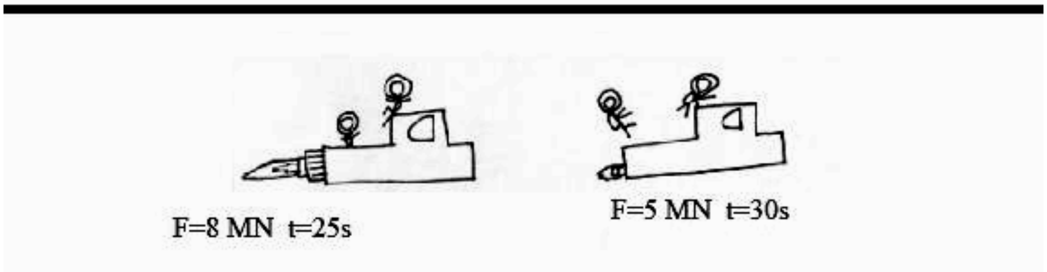
Rocket A



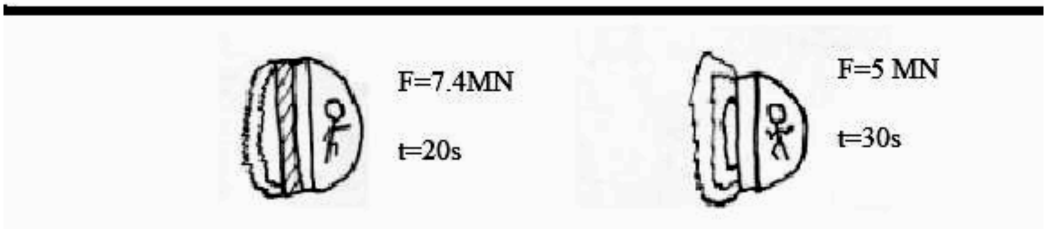
Rocket B



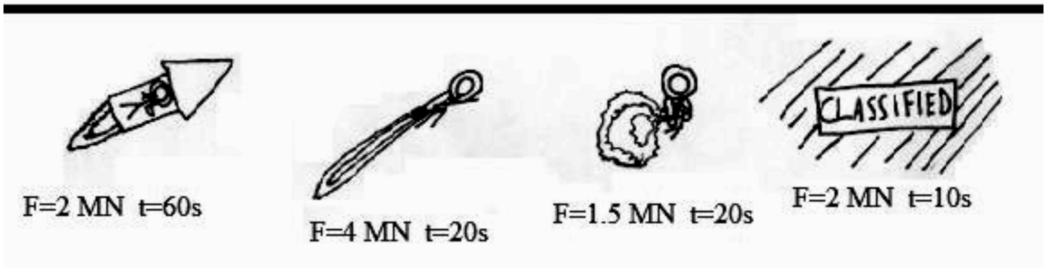
Rocket C



Rocket D



Rocket E



Follow up questions

1. How do you know which rocket engine can give you the most boost?

2. Who would win if rocket C increased its engine power to 9 MN in stage 2?

3. Who would win if rocket D increased its engine burn time to 50 s in stage 1?

4. Who would win if rocket B had a malfunction, cutting its burn time to 20 s?

5. Express the units of the *rocket boost index* using units of kg, m, and s.

6. What does the *rocket boost index* tell you about the rocket's motion?

7. What, in general, must be true about the gasses that are being shot from the back of the rockets in order to be consistent with your Explosion Rule?

8. Specifically, what can you say about the gasses that are shot from Rocket B?