

Momentum Problems

1. Astrid (mass 70 kg) is somehow stranded on some frictionless ice, and cannot walk at all. She has a heavy backpack of mass 10 kg.

a. How could she get off the ice?

If she throws the backpack, she will recoil in the opposite direction. (She won't be going fast, but she will be going...)



- b. If she can throw the backpack with a speed of 5 m/s, how fast would she go?

$$m_1 = 70 \text{ kg} \quad m_2 = 10 \text{ kg}$$

$$v_{1i} = 0 \text{ m/s} \quad v_{2i} = 0 \text{ m/s}$$

$$v_{1f} = ? \quad v_{2f} = 5 \text{ m/s}$$

$$\sum p_i = \sum p_f$$

$$0 + 0 = (70)v_{1f} + (10)(5)$$

$$70v_{1f} = -50$$

$$v_{1f} = -0.71 \text{ m/s}$$

2. A 500 kg cannon fires a 10 kg cannonball with a speed of 300 m/s.

a. What is the recoil speed of the cannon?

$$m_1 = 500 \text{ kg} \quad m_2 = 10 \text{ kg}$$

$$v_{1i} = 0 \text{ m/s} \quad v_{2i} = 0 \text{ m/s}$$

$$v_{1f} = ? \quad v_{2f} = 300 \text{ m/s}$$

$$\sum p_i = \sum p_f$$

$$0 + 0 = (500)v_{1f} + (10)(300)$$

$$500v_{1f} = -3000$$

$$v_{1f} = -6 \text{ m/s}$$

- b. Which object has a greater change in momentum?

same!

- c. Which object has a greater impulse?

same!

- d. Which object experiences a greater force?

same!

- e. Which object has a greater change in velocity?

cannonball

- f. Which object has a greater acceleration?

cannon ball

Momentum Problems

3. Two astronauts are floating motionless in space. They push off each other. The first astronaut has a mass of 150 kg, and after the push has a speed of 2 m/s. The other astronaut has a mass of 250 kg.

a. How fast is the other astronaut going after the push?

$$m_1 = 150 \text{ kg} \quad m_2 = 250 \text{ kg}$$

$$v_{1i} = 0 \text{ m/s} \quad v_{2i} = 0 \text{ m/s}$$

$$v_{1f} = 2 \text{ m/s} \quad v_{2f} = ?$$

$$\Sigma p_i = \Sigma p_f$$

$$0 + 0 = (150)(2) + (250)v_{2f}$$

$$250 v_{2f} = -300$$

$$v_{2f} = -1.2 \text{ m/s}$$

b. What is true about the directions of the two astronauts after the push?

opposite directions!



4. A 5 kg cart traveling at 2.5 m/s crashes and sticks to a 3 kg cart initially at rest. How fast are the two carts going when they are stuck together?

$$m_1 = 5 \text{ kg}$$

$$m_2 = 3 \text{ kg}$$

$$v_{1i} = 2.5 \text{ m/s}$$

$$v_{2i} = 0 \text{ m/s}$$

$$v_{1f} = v_{2f} \rightarrow = V$$

(stuck together)

$$\Sigma p_i = \Sigma p_f$$

$$(5)(2.5) + 0 = (5)V + (3)V$$

$$12.5 = 8V$$

$$V = 1.56 \text{ m/s}$$

5. A 1500 kg car traveling at 25 m/s skids on some ice, and crashes and sticks to a car of mass 2000 kg.

a. How fast are the two cars going right after the crash?

$$m_1 = 1500 \text{ kg}$$

$$m_2 = 2000 \text{ kg}$$

$$v_{1i} = 25 \text{ m/s}$$

$$v_{2i} = 0 \text{ m/s}$$

$$v_{1f} = v_{2f} \rightarrow \text{let's call it } V$$

$$\Sigma p_i = \Sigma p_f$$

$$(1500)(25) + 0 = (1500)V + (2000)V$$

$$37,500 = 3500 V$$

$$V = 10.7 \text{ m/s}$$

b. Which car experiences a greater change in momentum?

same!

6. A 1.5 kg cart moving at 3 m/s crashes and sticks to a second cart initially at rest. If they are going at 2 m/s when they are stuck together, what is the mass of the second cart?

$$m_1 = 1.5 \text{ kg}$$

$$m_2 = ?$$

$$v_{1i} = 3 \text{ m/s}$$

$$v_{2i} = 0 \text{ m/s}$$

$$v_{1f} = 2 \text{ m/s}$$

$$v_{2f} = 2 \text{ m/s}$$

$$\Sigma p_i = \Sigma p_f$$

$$(1.5)(3) + 0 = (1.5)(2) + (m_2)(2)$$

$$4.5 = 3 + 2m_2$$

$$1.5 = 2m_2$$

$$m_2 = 0.75 \text{ kg}$$

Momentum Problems

7. An archer shoots a 0.1 kg arrow with a speed of 60 m/s at an 0.5 kg apple. If the arrow sticks in the apple, what is the final speed of the apple and arrow?

$$m_1 = 0.1 \text{ kg} \quad m_2 = 0.5 \text{ kg}$$

$$v_{1i} = 60 \text{ m/s} \quad v_{2i} = 0 \text{ m/s}$$

stuck together! $v_{1f} = v_{2f} \rightarrow v$

$$\Sigma p_i = \Sigma p_f$$

$$(0.1)(60) + 0 = (0.1)v + (0.5)v$$

$$6 = 0.6v$$

$$\boxed{v = 10 \text{ m/s}}$$

8. Peggy (50 kg) and Bill (70 kg) are having an argument standing on an icy surface. Peggy pushes Bill so that Bill moves backward with a speed of 2 m/s?

- a. How fast does Peggy move after she pushes Bill?

$$m_1 = 50 \text{ kg} \quad m_2 = 70 \text{ kg}$$

$$v_{1i} = 0 \text{ m/s} \quad v_{2i} = 0 \text{ m/s}$$

$$v_{1f} = ? \quad v_{2f} = -2 \text{ m/s}$$

$$\Sigma p_i = \Sigma p_f$$

$$0 + 0 = (50)v_{1f} + (70)(-2)$$

$$0 = 50v_{1f} - 140$$

$$50v_{1f} = 140$$

$$\boxed{v_{1f} = 2.8 \text{ m/s}}$$

- b. Who experiences more force?

Same!

9. Nasir runs with a speed of 5 m/s and jumps on a stationary 7 kg skateboard. If Nasir's mass is 60 kg, how fast are Nasir and the skateboard moving?

$$m_1 = 60 \text{ kg} \quad m_2 = 7 \text{ kg}$$

$$v_{1i} = 5 \text{ m/s} \quad v_{2i} = 0 \text{ m/s}$$

stuck! $v_{1f} = v_{2f} \rightarrow v$

$$\Sigma p_i = \Sigma p_f$$

$$(60)(5) + 0 = (60)v + (7)v$$

$$300 = 67v$$

$$\boxed{v = 4.48 \text{ m/s}}$$

10. Darlene is enjoying a relaxing day on her 20 kg canoe, when she drops her cell phone into the lake. Darlene jumps off the boat and into the lake with a speed of 2.5 m/s and the boat moves in the opposite direction with a speed of 4 m/s. What is Darlene's mass?

$$m_1 = ? \quad m_2 = 20 \text{ kg}$$

$$v_{1i} = 0 \text{ m/s} \quad v_{2i} = 0 \text{ m/s}$$

$$v_{1f} = 2.5 \text{ m/s} \quad v_{2f} = -4 \text{ m/s}$$

$$\Sigma p_i = \Sigma p_f$$

$$0 + 0 = (m_1)(2.5) + (20)(-4)$$

$$0 = 2.5m_1 - 80$$

$$2.5m_1 = 80$$

$$\boxed{m_1 = 32 \text{ kg}}$$

Momentum Problems

- *11. A car traveling at 30 m/s skids on some ice and crashes and sticks to a car of mass 1500 kg that was initially at rest. The two cars move at 21 m/s when they are stuck together. What was the mass of the first car?

$$m_1 = ? \quad m_2 = 1500 \text{ kg}$$

$$v_{1i} = 30 \text{ m/s} \quad v_{2i} = 0 \text{ m/s}$$

$$v_{1f} = 21 \text{ m/s} \quad v_{2f} = 21 \text{ m/s}$$

$$\sum p_i = \sum p_f$$

$$(m_1)(30) + 0 = (m_1)(21) + (1500)(21)$$

$$30 m_1 = 21 m_1 + 31,500$$

$$9 m_1 = 31,500$$

$$\boxed{m_1 = 3500 \text{ kg}}$$

12. You are walking down the hall and you randomly over hear one student tell another student "Everyone knows that when two cars collide the smaller car always experiences more force." Is this statement correct? Explain.

Nope! Remember Newton's Third Law!

The forces will be equal and opposite.

The 2 cars will have equal & opposite: * Forces
* Impulses
* change in Momentum

But the smaller car will have
a larger: * acceleration
* change in velocity

Answers:

- | | | | | |
|----------------------|-------------|---|----------------|------------------|
| 1. a) throw backpack | b) 0.71 m/s | 2) 6 m/s | b, c, d.) same | e, f) cannonball |
| 3. a) 1.2 m/s | b) opposite | 4) 1.56 m/s | 5) a) 10.7 m/s | b) same |
| 6) 0.75 kg | 7) 10 m/s | 8. a) 2.8 m/s | b) same | 9) 4.5 m/s |
| 10) 32 kg | 11) 3500 kg | 12) Incorrect, Newton's 3 rd Law | | |