PHYSICS IN MOTION
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Unit 4B
Conservation of Momentum
Practice Problems TEACHER

Work each of the following problems. SHOW ALL WORK.

1. Two people stand facing each other at a roller skating rink then push off each other.

a. What is the momentum of the system before they push off each other?

The momentum of the system is zero because they are both at rest.

b. What must be the momentum of the system after they push off each other?

The momentum of the system after they push off each other must also be zero because momentum is conserved.

c. If the girl skater has a mass of 30 kg and moves backward at 5 m/s, what is the velocity of the boy skater if his mass is 50 kg?

$$p_i = p_f$$

$$p_i = 0$$
$$p_f = p_{boy_f} + p_{girl_f}$$
$$0 = m_{boy} v_{boy_f} + m_{girl} v_{girl_f}$$
$$-m_{boy} v_{boy_f} = m_{girl} v_{girl_f}$$
$$-(50\ kg) v_{boy_f} = (30\ kg)(5\ {}^{m}/_{s})$$
$$-(50\ kg) v_{boy_f} = 150\ kg\,{}^{m}/_{s}$$
$$v_{boy_f} = -3\ {}^{m}/_{s}$$

d. If the force applied between the two skaters occurs over 2.5 seconds, what is the force exerted on each of the skaters?

$$\Delta p = F\Delta t$$
$$m(\Delta v) = F\Delta t$$
$$(30\ kg)(5\ {}^{m}/_{s} - 0) = F(2.5\ s)$$
$$150\ kg\,{}^{m}/_{s} = F(2.5\ s)$$
$$F = 60\ N$$

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2. A 200 g blob of clay moves with a speed of 10 m/s towards a 300 g cart that is initially at rest.

a. What is the momentum of the system before the blob of clay strikes the cart?

$$p_{Total} = p_{clay} + p_{cart}$$
$$p_{Total} = m_{clay}v_{clay} + m_{cart}v_{cart}$$
$$p_{Total} = (0.2\,kg)(10\,{}^{m}\!/\!_{s}) + (0.3\,kg)(0\,{}^{m}\!/\!_{s})$$
$$p_{Total} = 2\,kg\,{}^{m}\!/\!_{s}$$

b. What must be the momentum of the system after they come together?

The momentum of the system must be 2 kg m/s, because momentum is conserved.

c. If the blob of clay sticks to the cart, with what speed will the clay and cart move after they come together?

$$p_i = p_f$$

$$p_f = p_{clay_f} + p_{cart_f}$$
$$2\,kg\,{}^{m}\!/\!_{s} = m_{clay}v_{clay_f} + m_{cart}v_{cart_f}$$
$$v_{clay_f} = v_{cart_f} = v_f$$
$$2\,kg\,{}^{m}\!/\!_{s} = m_{clay}v_f + m_{cart}v_f$$
$$2\,kg\,{}^{m}\!/\!_{s} = (0.2\,kg)v_f + (0.3\,kg)v_f$$
$$2\,kg\,{}^{m}\!/\!_{s} = (0.5\,kg)v_f$$
$$v_f = 4\,{}^{m}\!/\!_{s}$$

3. Two carts, each with a mass of 2.5 kg, move toward one another.

a. If the cart moving left is traveling at 10 m/s and the cart moving right is traveling at 8 m/s, what is the magnitude and direction of the total momentum of the system?

The direction will be to the left. Left is defined as the negative direction,

so the negative sign indicates the total momentum will be to the left.

$$p_{Total} = p_{left} + p_{right}$$
$$p_{Total} = m_{left}v_{left} + m_{right}v_{right}$$
$$p_{Total} = (2.5\,kg)(-10\,{}^{m}\!/\!_{s}) + (2.5\,kg)(8\,{}^{m}\!/\!_{s})$$
$$p_{Total} = -25\,kg\,{}^{m}\!/\!_{s} + 20\,kg\,{}^{m}\!/\!_{s}$$
$$p_{Total} = -5\,kg\,{}^{m}\!/\!_{s}$$

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Work each of the following problems. SHOW ALL WORK.

b. What is the total momentum of the system if the two carts have the same speed?

If the two carts have the same speed but are traveling in opposite directions, the total momentum of the system is zero because the objects have equal momenta in opposite directions.

4. An 800 kg car and a 1,600 kg truck move toward one another, both traveling at 15 m/s. In what direction will the two vehicles move after they collide? Show your calculations to prove your answer.

Because the 1,600 kg truck has more momentum, the two vehicles will move together in the initial direction of the truck.

$$p_{car} = m_{car} v_{car}$$
$$p_{car} = (800\ kg)(-15\ {}^{m}/_{s})$$
$$p_{car} = -12000\ kg\,{}^{m}/_{s}$$

$$p_{truck} = m_{truck} v_{truck}$$
$$p_{truck} = (1600\ kg)(15\ {}^{m}/_{s})$$
$$p_{truck} = 24000\ kg\,{}^{m}/_{s}$$

$$p_{total} = p_{car} + p_{truck}$$
$$p_{total} = -12000\ kg\,{}^{m}/_{s} + 24000\ kg\,{}^{m}/_{s}$$
$$p_{total} = 12000\ kg\,{}^{m}/_{s}$$

5. A woman stands in a boat at rest on a calm lake. She throws a 10 kg anchor off the front of the boat, which has a mass of 1,000 kg.

a. What is the initial momentum of the anchor-boat system?

The initial momentum of the anchor-boat system is zero because both objects are at rest.

b. In which direction will the boat move after the anchor is thrown?

The boat will move backward when the anchor is thrown forward because the anchor and the boat must have equal but opposite momenta so that the total momentum of the system remains zero.

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Work each of the following problems. SHOW ALL WORK.

c. How does the change in momentum of the anchor compare to the change in momentum of the boat?

Because the total momentum of the system must remain at zero, the anchor and the boat will have equal but opposite momenta; therefore, they both experience the same change in momentum but in opposite directions.

d. If the velocity of the anchor is 12 m/s, what is the velocity of the boat after the anchor is released?

$$p_i = 0$$
$$p_i = p_f$$

$$p_f = p_{anchor_f} + p_{boat_f}$$
$$0 = m_{anchor} v_{anchor_f} + m_{boat} v_{boat_f}$$
$$-m_{anchor} v_{anchor_f} = m_{boat} v_{boat_f}$$
$$-(10\ kg)(12\ {}^{m}\!/\!_{s}) = (1000\ kg) v_{boat_f}$$
$$-120\ kg\,{}^{m}\!/\!_{s} = (1000\ kg) v_{boat_f}$$
$$v_{boat_f} = -0.12\ {}^{m}\!/\!_{s}$$