Name ________________ Class ________ Date ________

Skills Worksheet

Math Skills

Momentum

After you study each sample problem and solution, work out the practice problems on a separate sheet of paper. Write your answers in the spaces provided.

Problem

Thoroughbred horses are among the fastest horses in the world and are used in famous racing events such as the Kentucky Derby. The mass of a thoroughbred is about 5.00×10^2 kg. If a horse with this mass is galloping with a momentum of 8.22×10^3 kg•m/s, what is its speed?

Solution

Step 1: List the given and unknown values.

Given: *mass*, $m = 5.00 \times 10^2$ kg

momentum, $p = 8.22 \times 10^3$ kg•m/s

Unknown: *speed*, $v = ?$ m/s

Step 2: Rearrange the momentum equation to solve for speed.

$$momentum = mass \times speed \qquad p = mv$$

$$\frac{p}{m} = \frac{\cancel{m}v}{\cancel{m}}$$

$$v = \frac{p}{m}$$

Step 3: Insert the known values into the equation, and solve.

$$v = \frac{8.22 \times 10^3 \text{ kg•m/s}}{5.00 \times 10^2 \text{ kg}}$$

$$v = 16.4 \text{ m/s}$$

Practice

1. A pitcher in a professional baseball game throws a fastball, giving the baseball a momentum of 5.83 kg•m/s. Given that the baseball has a mass of 0.145 kg, what is its speed?

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2. The maximum speed measured for a golf ball is 273 km/h. If a golf ball with a mass of 47 g had a momentum of 5.83 kg•m/s, the same as that of the baseball in the previous problem, what would its speed be? How does this speed compare to a golf ball's maximum measured speed?

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3. The World Solar Challenge in 1987 was the first car race in which all the vehicles were solar powered. The winner was the *GM Sunraycer*, which had a mass of 177.4 kg, not counting the driver's mass. Assume that the driver had a mass of 61.5 kg, so that the total momentum of the car and driver was 4.416×10^3 kg•m/s. What was the car's speed in m/s and km/h?

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Problem

Although larger than the Atlantic walrus, the Pacific walrus can swim with a speed of about 9.7 m/s. If the momentum of a swimming walrus is 1.07×10^4 kg•m/s, what is its mass?

Solution

Step 1: List the given and unknown values.

Given: *speed*, $v = 9.7$ m/s

momentum, $p = 1.07 \times 10^4$ kg•m/s

Unknown: *mass*, $m = ?$ kg

Step 2: Rearrange the momentum equation to solve for mass.

$$momentum = mass \times speed \qquad p = mv$$

$$\frac{p}{v} = \frac{m\cancel{v}}{\cancel{v}}$$

$$m = \frac{p}{v}$$

Step 3: Insert the known values into the equation, and solve.

$$m = \frac{1.07 \times 10^4 \text{ kg•m/s}}{9.7 \text{ m/s}}$$

$$m = 1.1 \times 10^3 \text{ kg}$$

Practice

4. The lightest pilot-driven airplane ever built was the *Baby Bird.* Suppose the *Baby Bird* moves along the ground without a pilot at a speed of 88.0 km/h, Under these circumstances the momentum of the empty plane would be only 2790 kg•m/s. What is the mass of the plane?

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5. The most massive automobile to have been manufactured on a regular basis was the Russian-made Zil-41047. If one of these cars were to move at just 8.9 m/s, its momentum would be 2.67×10^4 kg • m/s. Use this information to calculate the mass of a Zil-41047.

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6. The brightest, hottest, and most massive stars are the brilliant blue stars designated as spectral class O. As is the case of all stars, class O stars move with speeds that are measured in km/s.

a. If a class O star moves with a speed of 255 km/s and has a momentum of 8.62×10^{36} kg • m/s, what is the star's mass?

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b. A class O star typically has a mass of at least 10 solar masses (that is, 10 times the mass of the sun, which is 1.99×10^{30} kg). Express the mass calculated in part a in terms of solar masses.

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Problem

The Shinkansen, Japan's high-speed "bullet train," consists of several different versions of trains that have been in service since 1963. The 100-series trains consists of 16 steel cars that have a combined mass of 9.25×10^5 kg. The top speed of a regular 100-series train is 220 km/h. What would be the momentum of one of these trains?

Solution

Step 1: List the given and unknown values.

Given: *mass*, $m = 9.25 \times 10^5$ kg

speed, $v = 220$ km/h

Unknown: *momentum*, $p = ?$

Step 2: Perform any necessary conversions.

To find the speed in m/s, the value for speed must be multiplied by the number of meters in a kilometer and divided by the number of seconds in an hour.

$$v = 220\,\frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{1\,\cancel{\text{km}}} \times \frac{1\,\cancel{\text{h}}}{60\,\cancel{\text{min}}} \times \frac{1\,\cancel{\text{min}}}{60\text{ s}}$$

$$v = 61\text{ m/s}$$

Step 3: Write the equation for momentum.

$$\textit{momentum} = \textit{mass} \times \textit{speed} \qquad p = mv$$

Step 4: Insert the known values into the equation, and solve.

$$p = (9.25 \times 10^5\text{ kg}) \times (61\text{ m/s})$$

$$p = 5.6 \times 10^7\text{ kg}\bullet\text{m/s}$$

Practice

7. The 300-series Shinkansen trains consist of 16 aluminum cars with a combined mass of 7.10×10^5 kg. The reduction in mass from the 100-series enables the 300-series trains to reach a top speed of 270 km/h. What is the momentum of one of these trains at its top speed? Is the momentum of a 300-series train greater or less than the momentum of a 100-series train traveling at its top speed?

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8. The largest animal ever to have lived on Earth is the blue whale. Consider a blue whale with a mass of 1.46×10^5 kg and a top swimming speed of 24 km/h. What is the momentum of this whale at this speed?

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9. In 1996, Michael Johnson ran 200.0 m in 19.32 s. Johnson's mass at the time of his record-breaking run was about 77 kg. What was his momentum at his average speed?

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Mixed Practice

10. The highest land speed for a rail-guided vehicle was set in 1982 by a rocket sled at Holloman Air Force Base, in southern New Mexico. The sled was unmanned, but if it had a payload with a mass of 25 kg, the payload's momentum would have been about 6.8×10^4 kg • m/s. What was the speed, in m/s and km/h, of the payload and sled?

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11. The largest species of hummingbird is the *Patagonia gigas*, or the giant hummingbird of the Andes. This bird has a length of 21 cm and can fly with a speed of up to 50.0 km/h. Suppose one of these hummingbirds flies at this top speed. If its momentum is 2.78×10^{-1} kg • m/s, what is the hummingbird's mass?

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12. Although it cannot sustain its top speed for more than 8.65 s, the cheetah can run a distance of 274 m during that time. If a cheetah with a mass of 50.0 kg is moving at top speed, what is its momentum?

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13. The fastest speed recorded for a race car in the Indianapolis 500 was set in 1996 during a pre-race qualifying round. The minimum mass for a race car in the United States is 705 kg, so the minimum momentum of the record-setting car would have been 7.49×10^4 kg • m/s. What was the car's speed in both m/s and km/h?

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14. A hovercraft, also known as an air-cushion vehicle, glides on a cushion of air, allowing it to travel with equal ease on land or water. The first commercial hovercraft to cross the English Channel, the V. A-3, had an average speed of 96 km/h. Its momentum at this speed was 4.8×10^4 kg • m/s. What was the mass of the V. A-3?

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15. The danger that space debris poses to spacecraft can be understood in terms of momentum. At 160 km above Earth's surface, any object will have a speed of about 7.82×10^3 m/s. Consider a meteoroid (a small orbiting rock) that is about half a meter in diameter and has a mass of 423 kg. What is its momentum? How does this compare to the momentum of one car of a 100-series Shinkansen train, from the sample problem on the previous page, traveling at top speed?

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16. The fastest helicopter, the Westland Lynx, has a mass of 3.343×10^3 kg and a maximum momentum of 3.723×10^5 kg • m/s. What is its top speed?

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17. A student with a mass of 55 kg rides a bicycle at a speed of 5.0 m/s. The momentum of the bicycle and rider equals 320 kg • m/s.

a. What is the combined mass of the student and bicycle?

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b. How fast would the bicycle alone have to move in order to have the same momentum as that of the student and bicycle together?

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18. The S.S. *Norway* is a passenger ship with a mass of 6.9×10^7 kg and a top cruising speed of 33 km/h. What is the momentum of the S.S. *Norway* once it has reached its top cruising speed?

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MOMENTUM

1. $v = \frac{p}{m} = \frac{5.83 \text{ kg} \cdot \text{m/s}}{0.145 \text{ kg}} = 40.2 \text{ m/s}$

2. $v = \frac{p}{m} = \frac{5.83 \text{ kg} \cdot \text{m/s}}{(47 \text{ g}) \times \left(\frac{1 \text{ kg}}{1000 \text{ g}}\right)} = 124 \text{ m/s}$

This speed is greater than a golf ball's maximum measured speed.

3. $v = \frac{p}{m} = \frac{4.416 \times 10^3 \text{ kg} \cdot \text{m/s}}{177.4 \text{ kg} + 61.5 \text{ kg}} = 18.5 \text{ m/s}$

$18.5 \text{ m/s} \times \left(\frac{1 \text{ km}}{1000 \text{ m}}\right)\left(\frac{60 \text{ s}}{1 \text{ min}}\right)\left(\frac{60 \text{ min}}{1 \text{ h}}\right) = 66.6 \text{ km/h}$

4. $m = \frac{p}{v}$

$= \frac{2790 \text{ kg} \cdot \text{m/s}}{(88.0 \text{ km/h})\left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{1 \text{ h}}{60 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)}$

$= 114 \text{ kg}$

5. $m = \frac{p}{v} = \frac{2.67 \times 10^4 \text{ kg} \cdot \text{m/s}}{8.9 \text{ m/s}}$

$= 3.0 \times 10^3 \text{ kg}$

6. a. $m = \frac{p}{v} = \frac{8.62 \times 10^{36} \text{ kg} \cdot \text{m/s}}{255\,000 \text{ m/s}}$

$= 3.38 \times 10^{31} \text{ kg}$

b. $3.38 \times 10^{31} \text{ kg} \times \left(\frac{\text{solar mass}}{1.99 \times 10^{30} \text{ kg}}\right)$

$= 17.0 \text{ solar masses}$

7. $v = 270 \text{ km/h}$

$\times \left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{1 \text{ h}}{60 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$

$= 75 \text{ m/s}$

$p = mv = (7.10 \times 10^5 \text{ kg})(75 \text{ m/s})$

$= 5.3 \times 10^7 \text{ kg} \cdot \text{m/s}$

This momentum is slightly less than that of the 100-series train.

8. $v = 24 \text{ km/h}$

$\times \left(\frac{1000 \text{ m}}{1 \text{ km}}\right)\left(\frac{1 \text{ h}}{60 \text{ min}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$

$= 6.7 \text{ m/s}$

$p = mv = (1.46 \times 10^5 \text{ kg})(6.7 \text{ m/s})$

$= 9.8 \times 10^5 \text{ kg} \cdot \text{m/s}$

9. $p = mv = m\left(\frac{d}{t}\right) = (77 \text{ kg}) \times \left(\frac{200.0 \text{ m}}{19.32 \text{ s}}\right)$

$= 8.0 \times 10^2 \text{ kg} \cdot \text{m/s}$

10. $v = \frac{p}{m} = \frac{6.8 \times 10^4 \text{ kg} \cdot \text{m/s}}{25 \text{ kg}}$

$= 2.72 \times 10^3 \text{ m/s}$

$2.72 \times 10^3 \text{ m/s} \times \left(\frac{1 \text{ km}}{1000 \text{ min}}\right) \times \left(\frac{60 \text{ s}}{1 \text{ min}}\right)$

$\times \left(\frac{60 \text{ min}}{1 \text{ h}}\right) = 9.79 \times 10^3 \text{ km/h}$

11. $m = \frac{p}{v}$

$= \frac{2.78 \times 10^{-1} \text{ kg} \cdot \text{m/s}}{(50.0 \text{ km/h}) \times \left(\frac{1000 \text{ m}}{1 \text{ km}}\right) \times \left(\frac{1 \text{ h}}{60 \text{ min}}\right) \times \left(\frac{1 \text{ min}}{60 \text{ s}}\right)}$

$= 2.0 \times 10^{-2} \text{ kg}$

12. $p = mv = m\frac{d}{t} = (50.0 \text{ kg}) \times \left(\frac{274 \text{ m}}{8.65 \text{ s}}\right)$

$= 1.58 \times 10^3 \text{ kg} \cdot \text{m/s}$

13. $v = \frac{p}{m} = \frac{7.49 \times 10^4 \text{ kg} \cdot \text{m/s}}{705 \text{ kg}} = 106 \text{ m/s}$

$(106 \text{ m/s}) \times$

$\left(\frac{1 \text{ km}}{1000 \text{ m}}\right) \times \left(\frac{60 \text{ s}}{1 \text{ min}}\right) \times \left(\frac{60 \text{ min}}{1 \text{ h}}\right)$

$= 382 \text{ km/h}$

14. $m = \frac{p}{v}$

$= \frac{4.8 \times 10^4 \text{ kg} \cdot \text{m/s}}{(96 \text{ km/h}) \times \left(\frac{1000 \text{ m}}{1 \text{ km}}\right) \times \left(\frac{1 \text{ h}}{60 \text{ min}}\right) \times \left(\frac{1 \text{ min}}{60 \text{ s}}\right)}$

$= 1.8 \times 10^3 \text{ kg}$

15. $p = mv = (423 \text{ kg}) \times (7.82 \times 10^3 \text{ m/s})$

$= 3.31 \times 10^6 \text{ kg} \cdot \text{m/s}$

This is slightly less than the momentum of one car of the bullet train.

16. $v = \frac{p}{m} = \frac{3.723 \times 10^5 \text{ kg} \cdot \text{m/s}}{3.343 \times 10^3 \text{ kg}}$

$= 111.4 \text{ m/s}$

17. a. $m = \frac{p}{v} = \frac{320 \text{ kg} \cdot \text{m/s}}{5.0 \text{ m/s}} = 64 \text{ kg}$

b. $v = \frac{p}{m} = \frac{320 \text{ kg} \cdot \text{m/s}}{64 \text{ kg} - 55 \text{ kg}} = 36 \text{ m/s}$

18. $p = mv = (6.9 \times 10^7 \text{ kg})(33 \text{ km/h})$

$\times \left(\frac{1000 \text{ m}}{1 \text{ km}}\right) \times \left(\frac{1 \text{ h}}{60 \text{ min}}\right) \times \left(\frac{1 \text{ min}}{60 \text{ s}}\right)$

$p = 6.3 \times 10^8 \text{ kg} \cdot \text{m/s}$