Name _____ Class_____Date_____

Skills Worksheet

Math Skills

Newton's Second Law

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

The force of gravity between the moon and an object near its surface is much smaller than the force of gravity between Earth and the same object near Earth's surface. A bowling ball with a mass of 7.51 kg is pulled downward with an unbalanced force of –12.2 N. What is the acceleration of the falling bowling ball on the moon?

SOLUTION

Step 1: List the given and unknown values.

Given: *mass*, $m = 7.51$ kg

unbalanced force , $F = 12.2$ N

Unknown: *acceleration*, $a = ?$ m/s^2

Step 2: Rearrange the equation for Newton's second law to solve for acceleration.

force = mass × acceleration $F = ma$

$$\frac{F}{m} = \frac{\cancel{m}a}{\cancel{m}} = a$$

$$a = \frac{F}{m}$$

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

$$a = \frac{12.2\ \text{N}}{7.51\ \text{kg}} = \frac{12.2\ \text{kg} \cdot \text{m/s}^2}{7.51\ \text{kg}}$$

$$a = 1.62\ \text{m/s}^2$$

PRACTICE

1. The gravitational force that Earth exerts on the moon equals 2.03×10^{20} N. The moon's mass equals 7.35×10^{22} kg. What is the acceleration of the moon due to Earth's gravitational pull?

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2. Assume that a catcher in a professional baseball game exerts a force of –65.0 N to stop the ball. If the baseball has a mass of 0.145 kg, what is its acceleration as it is being caught?

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3. A type of elevator called a *cage* is used to raise and lower miners in a mine shaft. Suppose the cage carries a group of miners down the shaft. If the unbalanced force on the cage is 60.0 N, and the mass of the loaded cage is 1.50×10^2 kg, what is the acceleration of the cage?

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4. A 214 kg boat is sinking in the ocean. The force of gravity that draws the boat down is partially offset by the buoyant force of the water, so the net unbalanced force on the boat is –1,310 N. What is the acceleration of the boat?

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PROBLEM

A freight train slows down as it approaches a train yard. If a force of -3.8×10^6 N is required to provide an acceleration of –0.33 m/s^2, what is the train's mass?

SOLUTION

Step 1: List the given and unknown values.

Given: *unbalanced force, F* = -3.8×10^6 N

acceleration, a = –0.33 m/s^2

Unknown: *mass, m* = ? kg

Step 2: Rearrange the equation for Newton's second law to solve for mass.

$$force = mass \times acceleration \qquad F = ma$$

$$\frac{F}{a} = \frac{m\cancel{a}}{\cancel{a}} = m$$

$$m = \frac{F}{a}$$

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

$$m = \frac{-3.8 \times 10^6 \text{ N}}{-0.33 \text{ m/s}^2} = \frac{-3.8 \times 10^6 \text{ kg} \cdot \text{m/s}^2}{-0.33 \text{ m/s}^2}$$

$$m = 1.15 \times 10^7 \text{ kg}$$

PRACTICE

5. The tallest man-made structure at present is the *Warszawa Radio* mast in Warsaw, Poland. This radio mast rises 646 m above the ground, nearly 200 m more than the Sears Tower in Chicago. Suppose a worker at the top of the *Warszawa Radio* mast accidentally knocks a tool off the tower. If the force acting on it is 3.6 N, and its acceleration is 9.8 m/s^2, what is the tool's mass?

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6. The whale shark is the largest of all fish and can have the mass of three adult elephants. Suppose that a crane is lifting a whale shark into a tank for delivery to an aquarium. The crane must exert an unbalanced force of 2.5×10^4 N to lift the shark from rest. If the shark's acceleration while being lifted equals 1.25 m/s^2, what is the shark's mass?

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7. A house is lifted from its foundations onto a truck for relocation. The unbalanced force lifting the house is 2,850 N. This force causes the house to move from rest to an upward speed of 0.15 m/s in 5.0 s. What is the mass of the house?

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8. Because of a frictional force of 2.6 N, a force of 2.8 N must be applied to a textbook in order to slide it along the surface of a wooden table. The book accelerates at a rate of 0.11 m/s^2.

   a. What is the unbalanced force on the book?

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   b. What is the mass of the book?

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PROBLEM

The most massive train was put together in South Africa in 1989 and traveled 861 km. This freight train was over 7 km long and had a total mass of 6.94×10^7 kg. Suppose the train's acceleration from rest to an average speed of 38 km/h was 0.191 m/s^2. What then would be the size of the unbalanced force that the locomotives exerted on the cars of the train?

SOLUTION

Step 1: List the given and unknown values.

Given: *mass*, $m = 6.94 \times 10^7$ kg

acceleration, $a = 0.191$ m/s^2

Unknown: *unbalanced force*, $F =$? N

Step 2: Write out the equation for Newton's second law.

$force = mass \times acceleration$

$F = ma$

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

$F = (6.94 \times 10^7 \text{ kg}) \times (0.191 \text{ m/s}^2)$

$F = 1.33 \times 10^7 \text{ kg} \cdot \text{m/s}^2 = 1.33 \times 10^7 \text{ N}$

PRACTICE

9. In drag racing, acceleration is more important than speed, and therefore drag racers are designed to provide high accelerations. Suppose a drag racer has a mass of 1,250 kg and accelerates at a constant rate of 16.5 m/s^2. How large is the unbalanced force acting on the racer?

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10. A 5.22×10^7 kg luxury cruise ship is moving at its top speed as it comes into port. The ship then undergoes acceleration equal to –0.357 m/s^2 until it comes to rest at its anchorage. How large must the unbalanced force acting on the ship be in order to bring the ship to rest at the proper location?

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11. The force that stops a jet plane as it lands on the flight deck of an aircraft carrier is provided by a series of arresting cables. These cables act like extremely stiff rubber bands, stretching enough to keep from slowing the plane down too suddenly. A Hornet jet with a mass of 1.3×10^4 kg lands with an acceleration of –27.6 m/s^2. How large is the unbalanced force that the arresting cables exert on the plane?

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12. The giant sequoia redwood trees of the Sierra Nevada Mountains in California are said never to die from old age. Instead, an old tree dies when its shallow roots become loosened and the tree falls over. Removing a dead mature redwood from a forest is no easy feat, as the tree can have a mass of nearly 2.0×10^6 kg. Suppose a redwood with this mass is lifted with an upward acceleration of 0.85 m/s^2. How large is the unbalanced force lifting the tree?

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MIXED PRACTICE

13. Until it was recently discontinued, the fastest jet plane in the skies was the Lockheed SR-71 Blackbird. However, this plane did not reach its high speeds through large acceleration. The plane had a mass of 7.7×10^4 kg and was driven by an estimated unbalanced force of about 7.23×10^5 N. What was the acceleration of the Lockheed SR-71?

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14. Suppose an empty grocery cart rolls downhill in a parking lot. The cart has a maximum speed of 1.3 m/s when it hits the side of the store and comes to rest 0.30 s later. If an unbalanced force of –65 N stops the cart, what is the mass of the grocery cart?

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15. The fastest speed achieved on Earth for any object, with the exception of subatomic particles in particle accelerators, is 15.8 km/s. A device at Sandia Laboratories in Albuquerque, New Mexico, uses highly compressed air to accelerate a small metal disk to supersonic speeds. Suppose the disk reaches its top speed from rest in 1.0 s. If the disk has a mass of 0.20 g, what is the unbalanced force on the disk?

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16. "Maglev" trains use magnetic fields to levitate the train a few centimeters above the tracks. This design cuts down on friction so that the train can travel much faster than trains that roll on the tracks. The fastest maglev train is an experimental Shinkansen train consisting of three cars. This train has reached a speed of 550 km/h. Assume that the mass of this train is 1.33×10^5 kg and that the unbalanced force needed to accelerate the train to its top speed is 7.07×10^4 N. What is the train's acceleration?

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17. *Meteorites* are rocks that enter Earth's atmosphere and only partially burn up during entry, so that the remaining mass lands on Earth's surface. The speeds with which meteorites strike Earth's surface depend on their point of origin. If they were originally small rocks that orbited Earth, their impact speed might be as low as 10.0 km/s. If the small rocks orbited the sun, the speed with which they collide with Earth could be as large as 70.0 km/s. Suppose a meteorite collides with Earth with a force of -6.41×10^{12} N.

    a. What is the mass of the meteorite if its impact speed is 10 km/s, so that it has an acceleration of approximately -1.00×10^8 m/s^2 ?

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    b. What is the mass of the meteorite if its impact speed is 70 km/s, so that it has an acceleration of approximately -490×10^9 m/s^2?

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18. The largest acceleration that a human has ever endured occurred when a race car accidentally crashed into a wall. The car was traveling at a speed of 172.8 km/h when it hit the wall. The car came to a complete stop 2.72×10^{-2} s later.

    a. Calculate the acceleration of the car using the acceleration formula. Express your answer in both m/s^2 and in "g's." One g is equal to the free-fall acceleration of 9.8 m/s^2.

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    b. Suppose the driver of the car had a mass of 70.0 kg. What was the unbalanced force on his body as the car underwent negative acceleration?

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