Name _____ Date _____ Class _____

MATH SKILLS

Work

A car has run out of gas. Fortunately, there is a gas station nearby. You must exert a force of 715 N on the car in order to move it. By the time you reach the station, you have done 2.72×10^4 J of work. How far have you pushed the car?

1. List the given and unknown values.

   Given: *force, F* = 715 N

   work, W = 2.72×10^4 J

   Unknown: *distance, d* = ? m

2. Rearrange the work equation to solve for distance.

   $work = force \times distance$ $\qquad W = F \times d$

   $$\frac{W}{F} = \frac{F \times d}{F} = d$$

3. Substitute work and force values into the equation, and solve.

   $$d = \frac{2.72 \times 10^4 \text{ J}}{715 \text{ N}} = \frac{2.72 \times 10^4 \text{ N} \bullet \text{m}}{715 \text{ N}}$$

   d = 38.0 m

Your Turn to Think

1. You must exert a force of 4.5 N on a book to slide it across a table. If you do 2.7 J of work in the process, how far have you moved the book?
2. A catcher picks up a baseball from the ground. If the unbalanced force on the ball is 7.25×10^{-2} N and 4.35×10^{-2} J of work is done to lift the ball, how far does the catcher lift the ball?
3. The smallest bird is the Cuban bee hummingbird, which has a mass of only 1.7 g. If this bird did 8.8×10^{-4} J of work by exerting an upward force of 3.4×10^{-4} N, how far did it fly?
4. At the 1996 Summer Olympics, in Atlanta, Georgia, a mass of 260.0 kg was lifted for the first time ever in a clean-and-jerk lift. The lift, performed by Russian weightlifter Andrei Chemerkin, earned him the un-official title as "the world's strongest man." If Chemerkin did 6222 J of work in exerting a force of 2595 N, how high did he lift the mass?

Sample Problem

A building under construction requires building materials to be raised to the upper floors by cranes or elevators. A quantity of cement is lifted 76.2 m by a crane, which exerts a force on the cement that is slightly larger than the weight of the cement. If the work done in excess of the work done against gravity is 1.31×10^3 J, what is the unbalanced, overall force exerted on the cement?

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Work *continued*

1. List the given and unknown values.

Given: *distance*, $d = 76.2$ m

work, $W = 1.31 \times 10^3$ J

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

2. Rearrange the work equation to solve for force.

$$work = force \times distance \qquad W = F \times d$$

$$\frac{W}{d} = \frac{F \times d}{d} = F$$

3. Substitute work and distance values into the equation, and solve.

$$F = \frac{1.31 \times 10^3 \text{ J}}{76.2 \text{ m}} = \frac{1.31 \times 10^3 \text{ N} \bullet \text{m}}{76.2 \text{ m}}$$

$$F = 17.2 \text{ N}$$

Your Turn to Think

5. The world's most powerful tugboats are built in Finland. One of these boats can do 9.8×10^7 J of work through a distance of 35 m. What is the force exerted by the tugboat?
6. A child pulls a sled up a snow-covered hill. In the process, the child does 405 J of work on the sled. If she walks a distance of 15 m up the hill, how large a force does she exert on the sled?
7. One of the most powerful forklifts was built in Sweden in 1991. The lift is capable of lifting a 9.0×10^4 kg mass a distance of 2.0 m above the ground. If the work done by the forklift on the mass is 1.8×10^6 J, what is the force that the lift exerts on the mass?
8. The world's largest chandelier was built in South Korea and hangs in one of the department stores in Seoul. The chandelier's mass is 9.7×10^3 kg. Suppose the chandelier is lifted a distance of 11 m from the floor to the ceiling of the store. Lifting it requires that 1.05×10^6 J of work be done on the chandelier. What is the upward force exerted on the chandelier?

Sample Problem

An old house is being lifted by a type of crane from its foundation and moved by truck to another location. If the house, which weighs just under 1.50×10^4 N, is lifted 1.52 m from the foundation to the bed of the truck, what is the minimum amount of work done by the crane on the house?

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MATH SKILLS

Work *continued*

1. List the given and unknown values.

   Given: *force*, $F = 1.50 \times 10^4$ N

   distance, $d = 1.52$ m

   Unknown: *work*, $W = ?$ J

2. Write out the equation for work.

   $work = force \times distance$ $\qquad W = F \times d$

3. Substitute force and distance values into the work equation, and solve.

   $W = (1.50 \times 10^4 \text{ N}) \times 1.52 \text{ m} = 2.28 \times 10^4 \text{ N•m}$

   $W = 2.28 \times 10^4$ J

Your Turn to Think

9. After the house in the sample problem has been set on the truck bed, the truck accelerates until it reaches a constant speed. If the force required to move the house horizontally a distance of 75.5 m is 3150 N, how much work has been done on the house?

10. The largest passenger ship still in service is the SS *Norway*, which has a mass of 7.6×10^7 kg. The force required to accelerate the SS *Norway* from rest to its top cruising speed of 33 km/h is 1.6×10^6 N, assuming that this acceleration takes place over a distance of 2.0 km. How much work must be done on the ship during this period of acceleration?

11. Suppose an adult blue whale is stranded on a beach. The whale, which lies parallel to the shore, is 15 m from water deep enough for it to swim away in. A group of people line up along the side of the whale to push it back into the ocean. If the whale's weight is 1.5×10^6 N, and the force of friction that must be overcome by the people is 0.25 times the whale's weight, how much work must the people do on the whale in order to return it to the ocean?

12. In 1993, a generator built in Germany was shipped to India. With a mass of 1.24×10^5 kg, this generator was the most massive piece of equipment ever carried by an airplane. Suppose a force of 3.72×10^4 N was exerted on the generator in order to move it from a hangar to the airplane. If the distance between the hangar and the loading area of the plane was 57.2 m, how much work was done in moving the generator?

Mixed Review

13. A mover is loading a 253 kg crate of hammers onto a truck. The upward force on the crate is 2470 N, and 3650 J of work are required to raise the crate from the pavement to the truck bed. How far is the crate lifted?

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Work *continued*

14. The mover in problem (13) uses a ramp, which makes the task easier by requiring a smaller force to raise the crate to the truck bed. This force must be exerted over a greater distance, so the work done should be the same. In reality, because of the frictional force between the crate and the ramp, the work required is greater than that needed to lift the crate directly onto the truck. The mover does 4365 J of work sliding the crate up the ramp. The force the mover exerts on the crate is 1302 N. How long is the ramp?

15. A popular and dangerous circus act is the human cannonball, in which a person is shot from a cannon. Suppose the cannon has a barrel that is 3.05 m long and 1.67×10^4 J of work is done to accelerate the acrobat. What is the force exerted by the cannon on the acrobat?

16. The highest occupiable floor of any building is in the Sears Tower in Chicago. The elevators of the central tower of the building lift passengers 436 m above street level. If a continuous force of 2.23×10^4 N is exerted on one of these elevator cars as it travels from the ground to the top floor, how much work is done on the elevator car by the elevator's lifting mechanism?

17. A freight train leaving a train yard must exert a force of 2.53×10^6 N in order to increase its speed from rest to 17.0 m/s. During this process, the train must do 1.10×10^9 J of work. How far does the train travel?

18. In 1947, Northrop Aircraft developed and built a deceleration sled to test the effects of extreme forces on humans and equipment. In this sled, a test pilot with a mass of 70.0 kg undergoes a sudden negative acceleration of 4.90×10^2 m/s^2. This deceleration occurs over a distance of 8.05 m. How much work is done against the pilot's body during the deceleration?

19. A sunken treasure has a mass of 2140 kg, most of which is due to silver and gold coins. In order to make it easier to raise the treasure, a diver descends 17.5 m to where the treasure is located and attaches balloon-like bladders to each corner of the treasure chest. The diver then in-flates these bladders, so they provide buoyancy to the chest. The chest is still too heavy to float upward, but its weight has been largely counteracted by the inflated bladders, so that now it can be easily lifted by 4.27×10^4 J of work. What is the force that is exerted on the treasure in order to raise it to the water's surface?

20. A roller coaster must do work raising its cars to the highest point on the ride. From there, the cars coast at varying speed until they return to the starting point. Suppose a loaded roller coaster car must be raised 3.00×10^2 m from the ride's starting point to the top of the first rise. If 2.13×10^6 J of work must be done during this stage of the ride, how large is the force exerted on the car by the raising mechanism?