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Skill Sheet 1 — Speed Problems

This skill sheet will allow you to practice solving speed problems. To determine the speed of an object you need to know the distance traveled and the time taken to travel that distance. However, by rearranging the formula for speed, v = d/t, you can also determine the distance traveled or the time it took for the object to travel that distance, if you know the speed. For example,

Equation...	Gives you...	If you know...
$v = d/t$	speed	time and distance
$d = v \times t$	distance	speed and time
$t = d/v$	time	distance and speed

1. Solving problems

Solve the following problems using the speed equation. The first problem is done for you.

1. What is the speed of a cheetah that travels a total of 112.0 meters in 4.0 seconds?

$$\text{speed} = \frac{d}{t} = \frac{112.0\ \text{m}}{4.0\ \text{sec}} = \frac{28\ \text{m}}{\text{sec}}$$

2. A bicycle rider travels 60.0 kilometers in 3.5 hours. What is the cyclist's average speed?

3. What is the average speed of the car that traveled a total of 300.0 miles in 5.5 hours?

4. How much time would it take for the sound of thunder to travel 1,500 meters if sound travels at the speed of 330 m/s?

5. How much time would it take for an airplane to reach its destination if it traveled at an average speed of 790 kilometers/hour for a distance of 4,700 kilometers?

6. How far can a person run in 15 minutes if they run at an average speed of 16 km/hr? (Hint: Remember to convert minutes to hours)

7. A snail can move approximately 0.30 meters per minute. How many meters can the snail travel is 15 minutes?

2. Unit conversion

So far we have been mostly using the metric system for our problems. Now let's convert to the English System of measurement so that we can better understand the meaning of our answers to the questions above. Remember that there are 1,609 meters in one mile. Don't forget to include all units and cancel appropriately. *These questions refer to problems in part 1.*

1. In problem 1.1, what is the speed of the cheetah in miles/hour?

$$\frac{28 \text{ m}}{\text{sec}} \times \frac{1 \text{ mile}}{1609 \text{ m}} \times \frac{3600 \text{ sec}}{1 \text{ hour}} = \frac{63 \text{ miles}}{\text{hour}}$$

2. In problem 1.5, what is the speed of the airplane in miles/ hour?

3. In problem 1.6, what is the distance traveled in miles?

4. You now know that there are 1,609 meters in a mile. The number of feet in a mile is 5,280 feet. Use these equalities to answer the following problems.

   a. How many centimeters equals one inch?

   b. What is the speed of the snail in problem 1.7 in inches per minute?

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Skill Sheet 2 Acceleration Problems

This skill sheet will allow you to practice solving acceleration problems. Remember that acceleration is the rate of change in the speed of an object. In other words, at what rate does and object speed up or slow down? A positive value for acceleration refers to the rate of speeding up, and negative value for acceleration refers to the rate of slowing down. The rate of slowing down is also called deceleration. To determine the rate of acceleration you use the formula:

$$\text{Acceleration} = \frac{\text{Final speed} - \text{Beginning speed}}{\text{Change in Time}}$$

1. Solving acceleration problems

Solve the following problems using the equation for acceleration. Remember the units for acceleration are meters per second per second or m/sec^2. The first problem is done for you.

1. A biker begins to move from a speed of 0.0 m/sec to a final speed of 25.0 m/sec in 10.0 seconds. What is the acceleration of the biker?

$$\text{acceleration} = \frac{\frac{25.0\text{ m}}{\text{sec}} - \frac{0.0\text{ m}}{\text{sec}}}{10.0\text{ sec}} = \frac{\frac{25.0\text{ m}}{\text{sec}}}{10.0\text{ sec}} = \frac{2.5\text{ m}}{\text{sec}^2}$$

2. A skater increases her velocity from 2.0 m/sec to 10.0 m/sec in 3.0 seconds. What is the acceleration of the skater?

3. While traveling along the highway a driver slows from 24 m/sec to 15 m/sec in 12 seconds. What is the driver's acceleration? (Remember that a negative value indicates a slowing down or "deceleration.")

4. A parachute on a dragster racing-car opens and changes the speed of the car from 85 m/sec to 45 m/sec in a period of 4.5 seconds. What is the acceleration of the car?

5. The fastest land mammal, the cheetah, can accelerate from 0 mi/hr to 70.0 mi/hr in 3.0 seconds. What is the acceleration of the cheetah? Give your answer in units of mph/sec.

6. The Lamborghini Diablo sports car accelerates from 0.0 km/hr to 99.2 km/hr in 4.0 seconds. What is the acceleration of this car? Give your answer in units of kilometers per hour/sec.

7. Which has a greater acceleration, the cheetah or the Lamborghini Diablo? (To figure this out, you must remember that there are 1.6 km in one mile) Be sure to show your calculations.

2. Solving for other variables

Now that you have practiced a few acceleration problems, let's rearrange the acceleration formula so that we can solve for other variables such as for time and final speed.

$$\text{Final speed} = \text{beginning speed} + (\text{acceleration} \times \text{time})$$

$$\text{Time} = \frac{\text{Final speed} - \text{Beginning speed}}{\text{Acceleration}}$$

1. A cart rolling down an incline for 5.0 seconds has an acceleration of 4.0 m/sec^2. If the cart has a beginning speed of 2.0 m/sec, what is its final speed?

2. A car is accelerated at a rate of 3.0 m/sec^2. If its original speed is 8.0 m/sec, how many seconds will it take the car to reach a final speed of 25.0 m/sec?

3. A car traveling at a speed of 30.0 m/sec encounters an emergency and comes to a complete stop. How much time will it take for the car to stop if its rate of deceleration is -4.0 m/s^2?

4. If a car can go from 0.0 mi/hr to 60.0 mi/hr in 8.0 seconds, what would be its final speed after 5.0 seconds if its starting speed were 50.0 mph?

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Skill Sheet 3-A Newton's Second Law

As you work through the problems on this skill sheet, you will develop your understanding of Newton's second law of motion and how it relates to Newton's first law of motion. The second law states that the acceleration of an object is directly proportional to the force acting on the object and indirectly proportional to the mass of the object.

1. Newton's first law of motion

Newton's first law of motion (the law of inertia) states that the motion of an object will continue until an outside force changes this motion. The amount of force needed to change the motion of an object depends on the amount of *inertia* an object has. The inertia of an object is related to its mass. You need more force to move or stop an object with a lot of mass or inertia, than you need for an object with less mass or inertia.

In Newton's second law, the acceleration of an object is directly related to the force on an object, and inversely related to the mass of an object. This is shown the formula below.

$$\text{acceleration} = \frac{\text{Force}}{\text{mass}}$$

Units for acceleration are m/sec^2. Units for force are newtons (N). One newton is equivalent to 1 kg-m/sec^2. Units for mass are kilograms (kg). The equation for acceleration illustrates that acceleration is equal to the ratio of force to mass. This means that the force on an object causes it to accelerate, but the object's mass is a measure of how much it will resist acceleration.

2. Three ways to write Newton's second law of motion

In the formula for the second law of motion, acceleration equals force divided by mass. What does mass equal? What does force equal? Rearrange the equation to solve for mass. Then, rearrange the equation to solve for force.

What do you want to know?	What do you know?	The formula you will use
acceleration (a)	Force (F) and mass (m)	$\text{acceleration} = \frac{\text{Force}}{\text{mass}}$
mass (m)	acceleration (a) and Force (F)	
Force (F)	acceleration (a) and mass (m)	

3. Solving problems using Newton's second law

Solve the following problems using Newton's second law. The first two problems are done for you.

1. How much force is needed to accelerate a truck with a mass of 2,000 kg, at a rate of 3m/sec^2?

$$F = m \times a = 2{,}000\ \text{kg} \times \frac{3\ \text{m}}{\text{sec}^2} = 6{,}000\ \frac{\text{kg-m}}{\text{sec}^2} = 6{,}000\ \text{N}$$

2. What is the mass of an object that requires 15 N to accelerate it at a rate of 1.5 m/sec^2?

$$m = \frac{F}{a} = \frac{15\ \text{N}}{\frac{1.5\ \text{m}}{\text{sec}^2}} = \frac{\frac{15\ \text{kg-m}}{\text{sec}^2}}{\frac{1.5\ \text{m}}{\text{sec}^2}} = 10\ \text{kg}$$

3. What is the rate of acceleration of a 2,000.0-kilogram truck if a force of 4,200 N is used to make it start moving forward?

4. What is the acceleration of a 0.30-kilogram ball that is hit with a force of 25 N?

5. How much force is needed to accelerate a 68-kilogram skier at a rate of 1.2 m/sec^2?

6. What is the mass of an object that requires a force of 30 N to accelerate at a rate of 5 m/sec^2?

7. What is the force on a 1,000-kilogram elevator that is falling freely under the acceleration of gravity only?

8. What is the mass of an object that needs a force of 4,500 N to accelerate it at a rate of 5 m/sec^2?

9. What is the acceleration of a 6.4-kilogram bowling ball if a force of 12 N is applied to it?

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Skill Sheet 3-B Mass vs Weight

What is the difference between mass and weight? Why is it important to know these terms? This skill sheet will help you understand and correctly use mass and weight in problem solving.

mass	Mass is a measure of the amount of matter in an object. Mass is not related to gravity. The mass of an object does not change when it is moved from one place to another in the universe. Mass is commonly measured in grams or kilograms.
weight	Weight is a measure of the gravitational force between two objects. The weight of an object does change when the amount of gravitational force changes, as when an object is moved from Earth to the moon. Weight is commonly measured in newtons or pounds.

1. Why do mass and weight *seem* interchangeable?

People often talk about pounds and kilograms as if they are two units used to measure the same thing. They might say, for example, that a new baby weighs 8 pounds, or 3.63 kilograms. This statement implies that 8 pounds = 3.63 kilograms. This conversion makes sense *as long as* the baby stays on the surface of Earth.

On Earth's surface, the force of gravity acting on one kilogram is 2.22 pounds. So, if an object has a mass of 3.63 kilograms, the force of gravity acting on that mass *on Earth* will be:

$$3.63\text{ kg} \times \frac{2.22\text{ pounds}}{\text{kg}} = 8.06\text{ pounds}$$

On the moon's surface, however, the force of gravity acting on one kilogram is about 0.370 pounds. The same newborn baby, if she traveled to the moon, would still have a mass of 3.63 kilograms, but her weight would be just 1.34 pounds.

1. What is the weight (in pounds) of a 7.0-kilogram bowling ball on Earth's surface?

2. What is the weight of a 7.0-kilogram bowling ball on the surface of the moon?

3. What is the mass of a 7.0-kilogram bowling ball on the surface of the moon?

2. What does it mean when we say that weight is a force?

In everyday language, we think of weight as a measure of "how heavy" something is. A 25-pound toddler, for example, is a lot heavier to carry around than an 8-pound newborn.

Force, on the other hand, is defined as a push, pull, or any action that has the ability to change motion. So what does pushing or pulling have to do with weight?

To understand why we say that weight is a force, it helps to look at the scales used to measure weight. Grocery stores often have scales in the produce section. To use the scale, you put your produce (a bunch of bananas, for example) in a basket hanging from a spring. The force of gravity acting on the bananas *pulls* on the spring, causing it to stretch. The dial at the top measures how much the spring stretches. The dial shows the amount of pulling force in pounds.

Bathroom scales work much the same way, except that when you stand on the scale, you compress (*push*) the spring instead of pulling on it.

Balances, which are used to measure mass, work differently. A balance is like a see-saw with a pan on each end. In one pan, you put the object to be measured. In the opposite pan you put objects whose masses are known. When the two pans are balanced, you know the two sides have equal mass.

1. Describe what would happen to the spring in a bathroom scale if you were on the moon when you stepped on it. How is this different from stepping on the scale on Earth?

2. Would a balance function correctly on the moon? Why or why not?

3. What is free fall?

If you were to jump off of a 10-meter diving board with a scale attached to your feet, what would the scale read?

Until you hit the water, the scale would read zero pounds, even though you are very definitely still under the influence of gravity. It's just that you and the scale are falling at the same time, so there is nothing for your feet to push against.

A similar situation occurs when a space shuttle orbits the earth. The space shuttle is not so far away from Earth as to escape Earth's gravity. To understand what is happening, think about throwing a baseball. The baseball curves toward Earth due to the influence of gravity. Now think about throwing the baseball a little farther, and a little farther. What would happen if you could throw the baseball so hard that it kept falling *around* Earth? Then it would be like a space shuttle in orbit. The astronauts and everything inside the space shuttle seem to be weightless because they are in constant free fall.

4. Try this!

Take a bathroom scale into an elevator. Step on the scale.

1. What happens to the reading on the scale as the elevator begins to move upward?

2. What happens to the reading on the scale when the elevator stops moving?

3. What happens to the reading on the scale when the elevator begins to move downward?

4. Why does your weight appear to change, even though you never left Earth's gravity?

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Skill Sheet 3-C Momentum

This skill sheet will help you practice solving problems that involve momentum. The momentum of an object is equal to its mass times its velocity. When two objects collide, their momentum before the collision is equal to their momentum after the collision. This statement is called the law of conservation of momentum.

1. What is momentum?

A baseball bat and a ball are a pair of objects that collide with each other. Because of Newton's third law of motion, we know that the force the bat has on a baseball is equal to, but opposite in direction to the force of the the ball on the bat. The bat and the baseball illustrate that action and reaction forces come in pairs.

Similarly, the momentum of the bat before it hits the ball will affect how much momentum the ball has after the bat and ball collide. Likewise, the momentum of the ball coming toward the bat, determines how much force you must use when swinging the bat to get a home run. What is *momentum*?

The momentum (kg-m/sec) of an object is its mass (kg) multiplied by its velocity (m/sec). The equation for momentum where p equals momentum, m equals mass, and v equals velocity, is:

$$p = mv$$

$$p = \text{mass in kilograms} \times \text{speed in meters/sec}$$

2. The law of conservation of momentum

The *law of conservation of momentum* states that the momentum of a system is conserved. Two or more objects interacting may be called a system. The bat and ball are a system. This means that the momentum of the bat and ball is conserved. In other words, the momentum of the bat and ball before their collision is equal to the momentum of the bat and ball after their collision. A formula which summarizes this law and helps you complete the skill sheet is written below:

$$\text{Momentum of the system before a collision} = \text{Momentum of the system after a collision}$$

Momentum before Momentum after

$$m_1 v_1 - m_2 v_2 = m_1 v_1 - m_2 v_2$$

For example:

$$(\text{mass}_{\text{ball}})(\text{velocity}_{\text{ball}}) + (\text{mass}_{\text{bat}})(\text{velocity}_{\text{bat}}) = (\text{mass}_{\text{ball}})(\text{velocity}_{\text{ball}}) + (\text{mass}_{\text{bat}})(\text{velocity}_{\text{bat}})$$

As you solve the momentum problems that follow, REMEMBER that a positive velocity is in the opposite direction to a negative velocity.

3. Solving momentum problems

Find the momentum of the following objects. The first two problems have been done for you.

1. A 0.2-kg steel ball that is rolling at a velocity of 3.0 m/sec.

$$\text{momentum} = m \times v = 0.2\ \text{kg} \times \frac{3\ \text{m}}{\text{sec}} = 0.6\ \text{kg} \cdot \frac{\text{m}}{\text{sec}}$$

2. A 0.005-kg bullet with a velocity of 500 m/sec.

$$\text{momentum} = m \times v = 0.005\ \text{kg} \times \frac{500\ \text{m}}{\text{sec}} = 2.5\ \text{kg} \cdot \frac{\text{m}}{\text{sec}}$$

3. A 100-kg football player, a fullback, moving at a velocity of 3.5 m/sec.

4. A 75-kg football player, a defensive back, running at a velocity of 5 m/sec.

5. If a ball is rolling at a velocity of 1.5 m/sec and has a momentum of 10.0 kg-m/sec, what is the mass of the ball?

6. What is the velocity of an object that has a mass of 2.5 kg, and a momentum of 1,000 kg-m/sec?

4. Problems involving the law of conservation of momentum

Use the law of conservation of momentum formula below to answer the following problems. The first problem has been done for you.

Momentum before   Momentum after

$$m_1 v_1 - m_2 v_2 = m_1 v_1 - m_2 v_2$$

1. A 0.5-kg ball with a velocity of 2.0 m/sec hits another ball that is at rest and has a mass of 1.0 kg. If the first ball stops moving after it hits the second ball, what is the velocity of the second ball after the collision?

$$(0.5\text{ kg})\left(\frac{2.0\text{ m}}{\text{sec}}\right) - (0.5\text{ kg})\left(\frac{0.0\text{ m}}{\text{sec}}\right) = (0.5\text{ kg})\left(\frac{0.0\text{ m}}{\text{sec}}\right) + (1.0\text{ kg})(v_2)$$

$$\frac{(0.5\text{ kg})\left(\frac{2.0\text{ m}}{\text{sec}}\right)}{1.0\text{ kg}} = \frac{1.0\text{ m}}{\text{sec}} = v_2$$

2. A 1.0-kg ball with a velocity of 5 m/sec hits another 1.0-kg ball that is stationary. What is the momentum of each ball before the collision?

3. In question 2 above, what is the total momentum before and after the collision?

4. A 20-kg cart rolling to the right with a velocity of 20 m/sec collides with a 25-kg cart moving to the left with a velocity of 10 m/sec. What is momentum of each cart **before** the collision?

5. In question 4 above, what is the total momentum before and after the collision?

6. In question 5 above, the 20-kg cart rebounds to the left after the collision with a speed of 12.5 m/sec. What is the speed of the 25-kg cart after the collision?

7. In question 6 above, in which direction does the 25-kg cart move?

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Skill Sheet 3-D Applying Newton's Laws of Motion

In this skill sheet you will use Newton's laws of motion to solve application problems.

1. Reviewing Newton's law of motion

In the table below, state each of Newton's laws of motion. Use your own wording. For each law, describe an example of how each law is illustrated in real life.

Newton's laws of motion	Write the law here in your own words	Example of the law
The first law		
The second law		
The third law		

2. Practice using Newton's laws of motion

1. When Jane drives to work, she always places her purse on the passenger's seat. By the time she gets to work, her purse has fallen on the floor in front of the passenger seat. One day, she asks you to explain why this happens in terms of physics. What do you say?

2. You are waiting in line to use the diving board at your local pool. While watching people dive into the pool from the board, you realize that using a diving board to spring into the air before a dive is a good example of Newton's third law of motion. In the space below, explain how a diving board illustrates Newton's third law of motion.

3. Your shopping cart has a mass of 65 kilograms. In order to accelerate the shopping cart down an aisle at 0.30 m/sec^2, what force would you need to use or apply to the cart?

4. A small child has a wagon with a mass of 10 kilograms. The child pulls on the wagon with a force of 2 newtons. What is the acceleration of the wagon?