Density of Matter

Fast Track GRASP Math Packet

Photo by Ben Stephenson (Wikimedia Commons)

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Welcome!

Congratulations on deciding to continue your studies! We are happy to share this study packet on the density of matter. We hope that that these materials are helpful in your efforts to earn your high school equivalency diploma. This group of math study packets will cover mathematics topics that we often see on high school equivalency exams. If you study these topics carefully, while also practicing other basic math skills, you will increase your chances of passing the exam.

Please take your time as you go through the packet. You will find plenty of practice here, but it's useful to make extra notes for yourself to help you remember. You will probably want to have a separate notebook where you can recopy problems, write questions and include information that you want to remember. Writing is thinking and will help you learn the math.

After each section, you will find an answer key. Try to answer all the questions and then look at the answer key. It's not cheating to look at the answer key, but do your best on your own first. If you find that you got the right answer, congratulations! If you didn't, it's okay. This is how we learn. Look back and try to understand the reason for the answer. Please read the answer key even if you feel confident. We added some extra explanation and examples that may be helpful. If you see a word that you don't understand, try looking at the *Vocabulary Review* at the end of the packet.

We also hope you will share what you learn with your friends and family. If you find something interesting in here, tell someone about it! If you find a section challenging, look for support. If you are in a class, talk to your teacher and your classmates. If you are studying on your own, talk to people you know or try searching for a phrase online. Your local library should have information about adult education classes or other support. You can also find classes listed here: **http://www.acces.nysed.gov/hse/hse-prep-programs-maps**

You are doing a wonderful thing by investing in your own education right now. You have our utmost respect for continuing to learn as an adult.

Please feel free to contact us with questions or suggestions.

Best of luck!

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Vocabulary

It is important to understand mathematical words when you are learning new topics. The following vocabulary will be used a lot in this study packet:

compact · cube · cubic · density · mass · matter · metric · volume

In this first activity, you will think about each word and decide how familiar you are with it. For example, think about the word "cube." Which of these statements is true for you?

- I know the word "cube" and use it in conversation or writing.
- I know the word "cube," but I don't use it.
- I have heard the word "cube," but I'm not sure what it means.
- I have never heard the word "cube" at all.

In the chart on the next page, read each word and then choose one of the four categories and mark your answer with a ✔ (checkmark). Then write your best guess at the meaning of the word in the right column. If it's easier, you can also just use the word in a sentence.

Here's an example of how the row for "area" might look when you're done:

Word	I know the word and use the word	I know the word but don't use it	I have heard the word, but I'm not sure what it means	I have never heard the word	My best guess at the meaning of the word (or use the word in a sentence)
cube	✓				like a box, all the sides are the same length

Complete the table on the next page.

Word	I know the word and use the word	I know the word but don't use it	I have heard the word, but I'm not sure what it means	I have never heard the word	My best guess at the meaning of the word (or use the word in a sentence)
compact					
cube					
cubic					
density					
mass					
matter					
metric					
volume					

Introduction

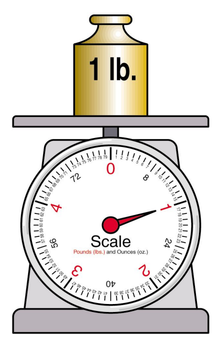
Density can be used to measure many different things. For example, how many people live in a place and the weight of gold are both related to density. This packet focuses on the density of matter, which is an important topic in science and will help you understand the high school equivalency math and science exams. You will also practice reading graphs and tables, which is an important skill on exams and for understanding information in the world. The density of matter is concerned with how compact or "pushed together" a substance is. Have you ever wondered why a helium-filled balloon rises in the air? Why some things float in water and others sink? How weather systems produce wind and rain? Density will help you understand each of these.

The density of matter is similar to population density, which is a way of describing how crowded a place is with people. Places where people are spread out, like the country, have low population density. Places where people live close together, like cities, have high population density. (The other half of our study materials on density will give you practice in **Population Density**.)

There is an old riddle that asks, "Which is heavier, a pound of feathers or a pound of rocks?"

vs.

When you first hear the question, you might think a pound of rocks is the answer, because rocks are heavier than feathers. Feathers are light and rocks are heavy, so a pound of rocks is heavier than a pound of feathers. Right?!



However, the riddle tells you that the feathers and the rocks are both one pound in weight. It's a trick question. A pound of feathers and a pound of rocks weigh the same amount. If you put the feathers on one scale and then put the rocks on another scale, they would both weigh 1 pound.

What if you changed the riddle and asked, “Which would take up more space, a pound of feathers or a pound of rocks?” Or you could make the riddle even more dramatic: “Which would take up more space, a TON of feathers or a TON of rocks?” (A ton is 2,000 pounds.)

A pound of feathers is bigger than a pound of rocks. And a ton of feathers is MUCH bigger than a ton of rocks. A ton of rocks might fill a box about 3 feet on each side. A ton of feathers would fill a small 2-bedroom apartment, from floor to ceiling.

There is definitely something different about a few rocks and a lot of feathers, even though they might weigh the same amount. The difference is *density*. Rocks have a high density and feathers have a low density.

Here are a few more examples. A bowling ball and a basketball are about the same size, but a bowling ball is much heavier. A bowling ball is heavier for its size and therefore has a higher density than a basketball. A metal spoon and a plastic spoon are the same size, but a metal spoon is heavier. The metal spoon has a higher density than a plastic spoon. If two things are the same size and one is heavier, then it has a higher density. In science, density is a measure of how heavy something is for its size.

Matter

What is Matter?

In this packet, you will learn more about the scientific idea of density. In order to understand density, it’s important to understand something called matter. Matter is an important concept in chemistry and physics. Understanding matter is actually the basis for all sciences. But what is matter?

Here is an everyday definition: Matter is STUFF in the world. For example, water, people, clothes, phones, grass, food, metal, and air are all examples of matter.

And here’s a scientific definition: *Matter is anything that has mass and volume*.

To understand the scientific definition of matter, we need to understand *mass* and *volume*.

Mass

A bowling ball and a basketball are about the same size. But the bowling ball is made of more matter. In other words, a bowling ball has a greater *mass* than a basketball. Mass is a measure of the amount of matter present in a given volume of a substance. Mass is also a

measurement of how much something weighs. We use a scale to measure mass and we might use pounds or kilograms to describe how heavy something is. Does a coffee cup, building or grain of rice have mass? Yes. They weigh different amounts, large and small, but they all have weight, so we would say they have mass. Does light have weight? No. Light warms the Earth and helps plants grow, but it has no weight. Since it has no weight, then it has no mass. So light is not matter.

Volume

Anything that takes up space has *volume*. Volume is a measure of the size of an object or how much space it takes up. Does a coffee cup occupy space? Does a building take up space? How about a grain of rice? The answer to all of these is yes. Whether large or small, each of these objects take up space and therefore have volume. Do feelings have volume? No. Emotions are important, but they don't take up space, so emotions are not matter.

Fill in the chart below. You can check your answers in the [Matter - Answer Key](#).

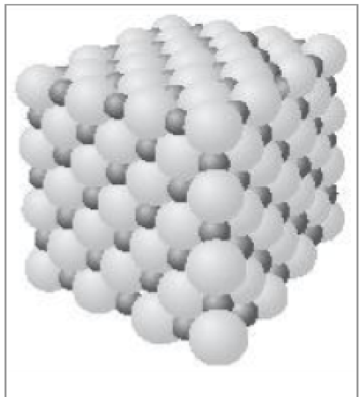
1) Add more examples to each column in the table below. Anything that has mass and volume should be on the left side.

Matter	Not matter
building	light
grain of rice	emotions

Atoms

A metal spoon and a plastic spoon are the same size, but the metal spoon is heavier. Why? This is because the metal spoon is made of more matter than the plastic spoon. The matter in the metal spoon is more compact (packed together).

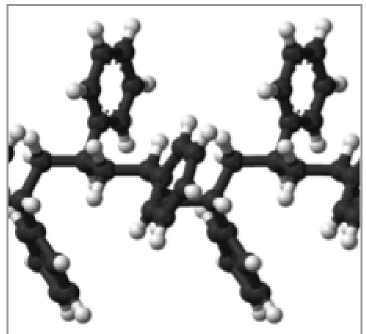
Matter is made of atoms. Atoms are very, very small bits of matter that make up everything around us. For example, there are oxygen atoms in the air we breathe in and there are carbon and oxygen atoms in the air we breathe out.



steel

Metal spoons are often made from steel, which is made up of carbon and iron atoms. The carbon and iron atoms are packed tightly together. More matter fits in a smaller space, which makes steel heavy for its size. Steel is made mostly of iron atoms, which are heavier than carbon and hydrogen atoms.

Plastic spoons are often made of polystyrene, a kind of plastic which is made up of carbon and hydrogen atoms. In polystyrene, the carbon and hydrogen atoms are spaced apart and loosely connected. Less matter fits in the same space, which makes plastic lighter for its size than steel. The carbon and hydrogen atoms in polystyrene are also lighter than iron atoms.



polystyrene

Hydrogen, oxygen, carbon, helium, gold, silver, and iron are examples of *elements*, substances that are made of one particular kind of atom and cannot be broken down into simpler substances.

Mass (or Weight)

When we use the word *mass* in this packet, we mean the weight of an object. If you continue studying science, you will learn that there is actually a difference between mass and weight. For what we are studying now, the difference isn't important, but technically, mass is the amount of stuff (matter) in an object. Let's say we're talking about an apple. The mass is a measurement of how much matter is in the apple. The apple's weight, on the other hand, is a measure of how much gravity pulls the apple towards Earth. The more matter in an object, the more gravity pulls. Things with more matter are heavier. Weighing an object will tell you much mass it has. If you're always weighing stuff on Earth, the difference between mass and weight doesn't matter very much.

On the other hand, let's imagine you were lucky enough to fly to the Moon and brought the apple with you. The mass of the apple would stay the same. It is still the same apple and has the same amount of matter. However, if you weighed the apple on the Moon, the apple would weigh less on the Moon, since the Moon's gravitational pull is weaker than Earth's. For now, just remember that mass basically means how much something weighs (especially when we're on Earth).

In the American system of measurement, there are three common measures of mass: *ounces* (oz.), *pounds* (lbs.) and *tons*. There are 16 ounces in a pound and 2,000 pounds in a ton.

In the rest of the world, people use the International System (SI) of measurement, also known as the metric system. American scientists, health care workers, and others also use the metric system of measurement. In the metric system, the basic unit of mass is the *kilogram*. A kilogram is 1,000 *grams*. To understand the size of a gram, imagine a paperclip, which weighs about 1 gram. So, 1,000 paperclips would weigh about 1 kilogram.

Here are some sample objects and their weights in the American system and the International System:

The weight of…	**is about…**	**and is also about…**
a large paperclip	.04 ounces	1 gram
5 quarters ($1.25)	1 ounce	28 grams
1 liter bottle of water	2.2 pounds	1 kilogram
a package of spaghetti	1 pound	½ kilogram
an average man	195 pounds	88 kilograms
a small car	1 ton (2,000 pounds)	907 kilograms

2) How many grams would two paper clips weigh? ________________

   How many ounces would two paper clips weigh? ________________

3) How many grams would five paper clips weigh? _______________

   How many ounces would five paper clips weigh? _______________

4) How many grams would 10 paper clips weigh? _______________

   How many ounces would 10 paper clips weigh? _______________

5) How many grams would 10 quarters weigh? _______________

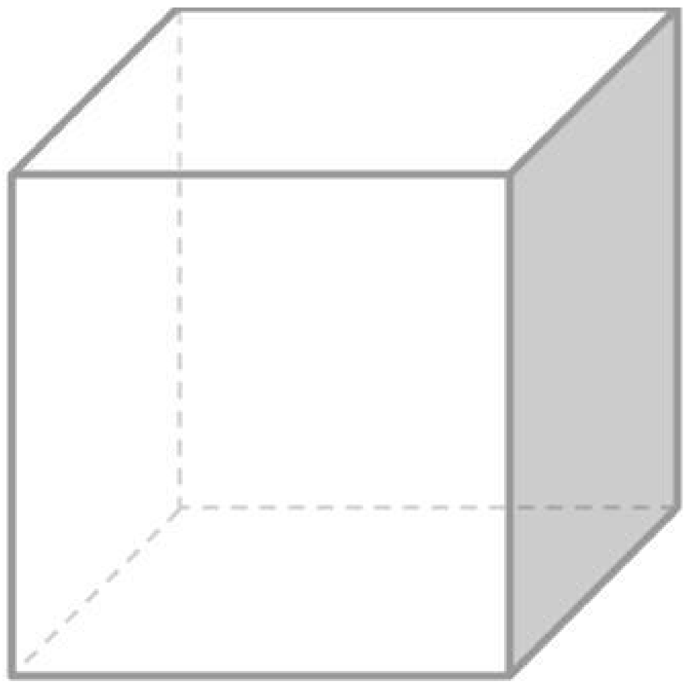
   How many ounces would 10 quarters weigh? _______________

6) How many grams would five dollars in quarters weigh? _______________

   How many ounces would five dollars in quarters weigh? _______________

Volume

In order to order to understand the density of matter, we need to understand a mathematical definition of *volume*, which is the amount of space an object occupies. In math and science, we measure volume by counting *cubes*. A cube is a box-shaped object where each side is the same length.



This is picture of a cube. The width, height and length are the same length.

When we measure volume, we imagine filling an object with cubes and then count how many cubes will fit inside the object. You can think about this as the number of cubes that would fill the same amount of space as the object or how many cubes would fit inside it. Think about the volume of an apple. You can't fill an apple with cubes, but you could estimate how many cubes you would need to take up the same amount of space as the apple.

Volume can be measured with cubes of many different sizes. For example, the volume of a cardboard box might be measured with cubic inches or cubic centimeters, and the volume of an ocean with cubic miles or cubic kilometers. The cubes used are all the same shape, but they vary in size. Each side of the cube is the length of the unit (inches, centimeters, miles, kilometers, etc.).

When we use the word *volume*, we are talking about how much space each object occupies. The things we use to measure that space are cubic units. The volume of the cereal, milk and juice above could all be measured with cubic units.

We use the word *unit* to refer to the size of the cubes we are using. In the American system, our units for volume are cubic inches, cubic feet and cubic miles. In the metric system, the units for volume are cubic centimeters, cubic meters and cubic kilometers.

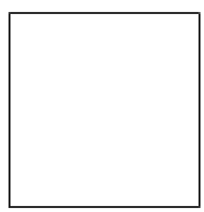
Note: It's important to remember the difference between length, area and volume. Consider how we use different kinds of inches for each measurement:

Length is a measure of distance.

1 inch

We could measure the length of a pencil in inches.

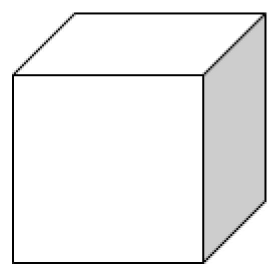
Area is a measure of the size of a flat surface.



1 square inch

We could measure the area of a wall in square inches.

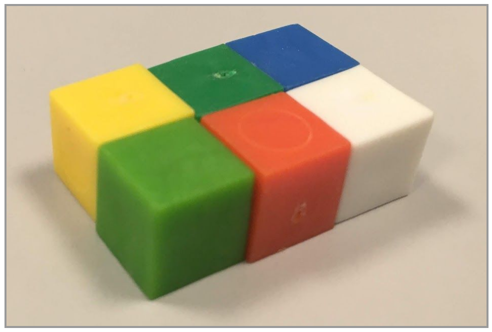
Volume is a measure of 3-dimensional space.



1 cubic inch

We could measure the volume of a moving truck in cubic inches.

Let's think about the volume of the 2×3 figure below. It is made of plastic cubes that are 1 centimeter on each side.



How many cubes are there in total? *6.*

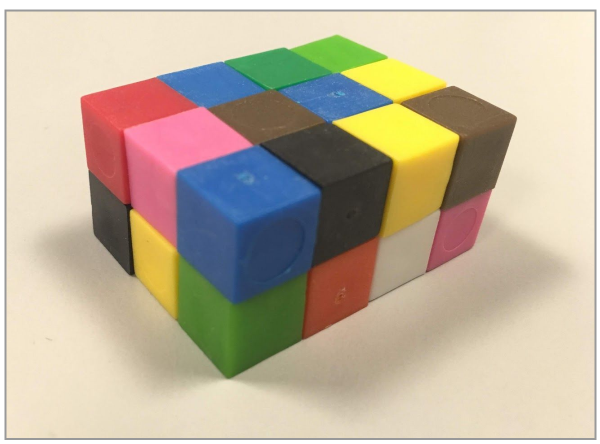
What is the size of each of these cubes? *A cubic centimeter*.

What is the volume of this collection of cubes? *6*

Yes, but 6 what? *6 cubic centimeters.*

Each cube is 1 cubic centimeter and there are 6 in total. We call them *cubic centimeters* because each one is in the shape of a cube and measures 1 centimeter on each size.

Look at this stack.



7) How many cubes are in the top layer of this 3×4×2 stack? _______

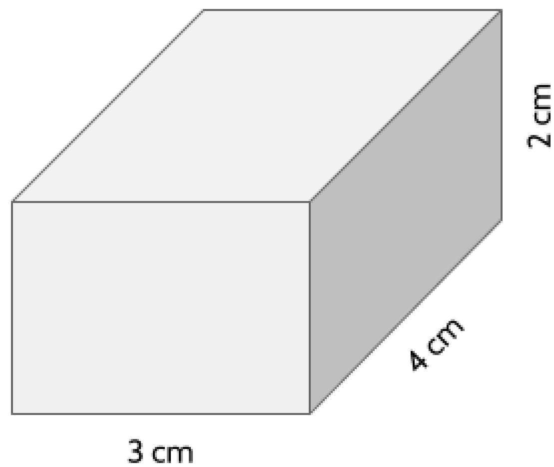
8) How many cubes are in the bottom layer of the stack? _______

9) How many cubes are there total? _______ cubic centimeters
(This is the volume of this stack of cubes.)

How did you determine the volume of the stack above? Counting the number of cubes is a perfectly good way to find out the volume, but what if the object isn't made of cubes you can see and count?

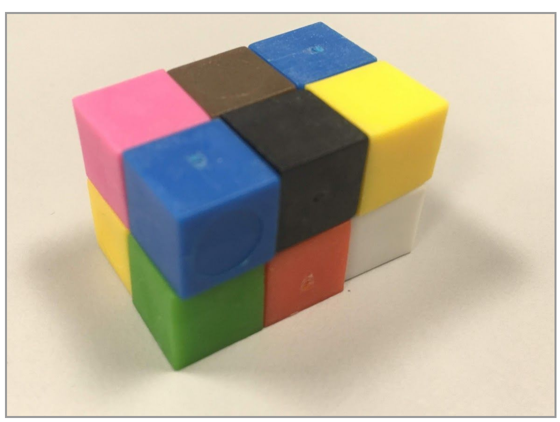
You can still visualize cubes in your mind and count them. Or you can figure out the total number of cubes in a stack multiplying the length by the width by the height. The stack on the previous page is 3 centimeters in length, 4 centimeters in width, and 2 centimeters high. 3 times 4 is 12 and 12 times 2 is 24, so there are 24 cubes. You can confirm this by counting them.

The volume of the stack = 3 cm × 4 cm × 2 cm = 24 cubic cm.



By the way, this shape is called a *rectangular prism*. It's like a cube, but not all the sides are the same length. Each of the faces (sides) is a rectangle. A cardboard box is an example of a rectangular prism.

10) What is the volume of the stack below? ________ cubic _________________



In the examples above, we used cubic centimeters to measure volume. If you were measuring something much larger, you probably wouldn't use cubic centimeters. For example, you might use cubic meters to measure the volume of a room. To do this, you can imagine lots of cubes, each with a width and length of 1 meter, filling all the space in the room. The room might have a volume of 149 cubic meters. This could also be expressed as 149,000,000 cubic centimeters. Both measurements are correct, but using cubic meters can be a lot less messy.

When you are measuring volume, it is important to make note of the size of the units you are using. Always include the unit: cubic inches, cubic centimeters, cubic feet, cubic meters, etc.

Cubic units can be written in many different ways:

cubic inches *cu. in.* in^3	*cubic feet* *cu. ft.* ft^3	*cubic miles* *cu. mi.* mi^3
cubic centimeters *cu. cm.* cm^3	*cubic meters* m^3	*cubic kilometers* km^3

Check your understanding: Which of these means the same as: *What is the volume of the stack?*

A) How long is the stack?

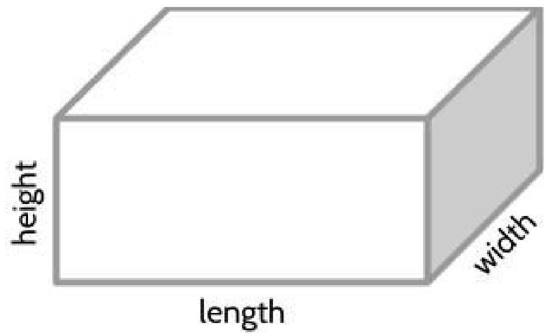
B) How many squares cover the surface?

C) How many cubes fill the space inside?

D) What is the length times the width?

Answer:

Choice C (*How many cubes would you need to fill it?*) means the same as *What is the volume of the stack?* Volume is a 3-dimensional measurement. C is the only question that is about 3-dimensional space. In the figure below, you can see the 3 dimensions: height, length and width.



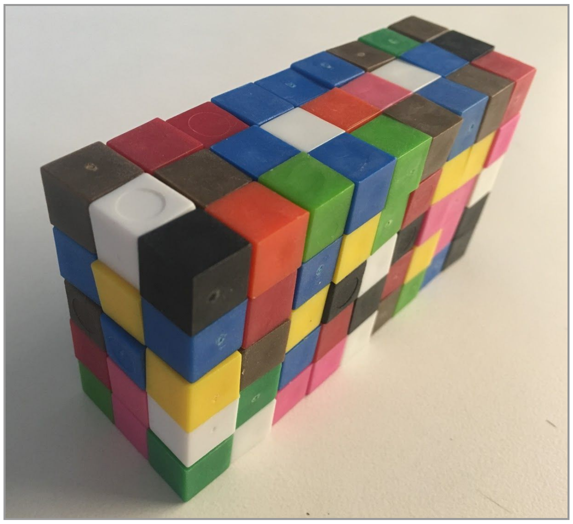
The other choices are wrong for different reasons.

A) *How long is the stack?* is about the length of the stack which would be measured with centimeters, not cubic centimeters.

B) *How many squares cover the surface?* is about the area of the stack. This might be appropriate if we wanted to know how much paper it would take to cover the outside of the stack, but it doesn't tell us the volume. Area is measured in square centimeters, not cubic centimeters.

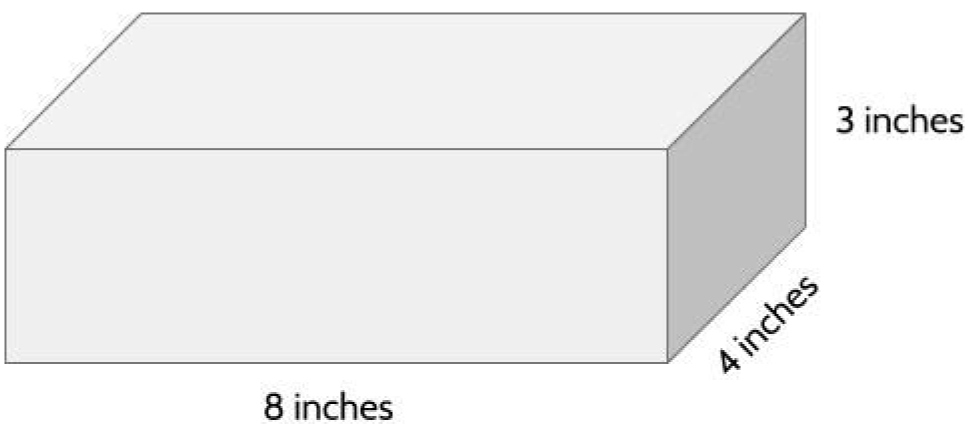
D) *What is the length times the width?* is a question about area, not volume.

Find the volume of the following figures.

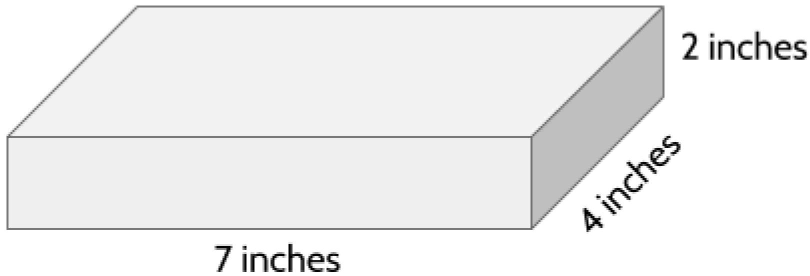
11) 

Volume = ____

(*Remember to include units along with the number of cubes.*)

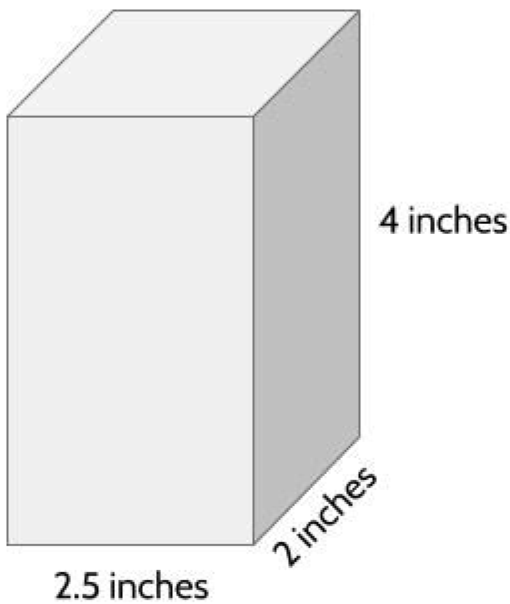
12) 

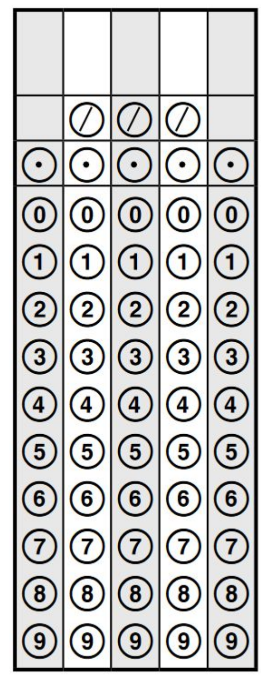
Volume = __________ cubic inches



13)

Volume = __________ in^3





14)

Enter the volume in cubic inches in the grid on the right.

15) Height = 4 centimeters
Length = 5 centimeters
Width = 3 centimeters

Volume = ____________________________________

16) Height = 7 feet
Length = 8 feet
Width = .5 feet

Volume = ____________________________________

Does it go better with mass or with volume? Put a checkmark in the correct column.

		mass	volume
17)	How much space something takes up		
18)	Kilograms		
19)	Heaviness		
20)	Size		
21)	Weigh it on a scale		
22)	Cubic inches		
23)	Grams		
24)	Cubic centimeters		
25)	Ounces		
26)	Pounds		
27)	Weight		

28) Dice are examples of cubes. Each of the edges have the same length and each face is a square.

How many sides do dice have?

Matter - Answer Key

1) **Matter**: There are an infinite number of other examples of matter. Just make each of your examples have mass (weight) and volume. If you look around a room, almost everything you see is made of matter: Shoes, books, plates, food, walls, etc. Other things that are really small can be made of matter as well: Bacteria, viruses, cells, and atoms.

   Not matter: If something doesn't have mass or volume, then it isn't matter. More examples include: Sound, heat, gravity, magnetism, radio waves, thoughts, and memories.

2) 2 grams, .08 ounces

3) 5 grams, .2 ounces

4) 10 grams, .4 ounces

5) 56 grams, 2 ounces

6) 112 grams, 4 ounces

7) 12

8) 12

9) 24 cubic centimeters

10) 24 cubic centimeters

11) 135 cubic centimeters

12) 96 cubic inches

13) 56 in^3

14) 20

15) 60 cubic centimeters

16) 28 cubic feet

17) volume

18) mass

19) mass

20) volume

21) mass

22) volume

23) mass

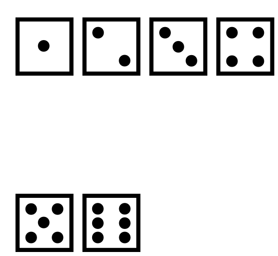
24) volume

25) mass

26) mass

27) mass

28) All cubes have 6 sides (called faces in geometry). On a die (another way of saying 1 "dice"), each face has a different number of dots. These are the 6 faces of a 6-sided die:



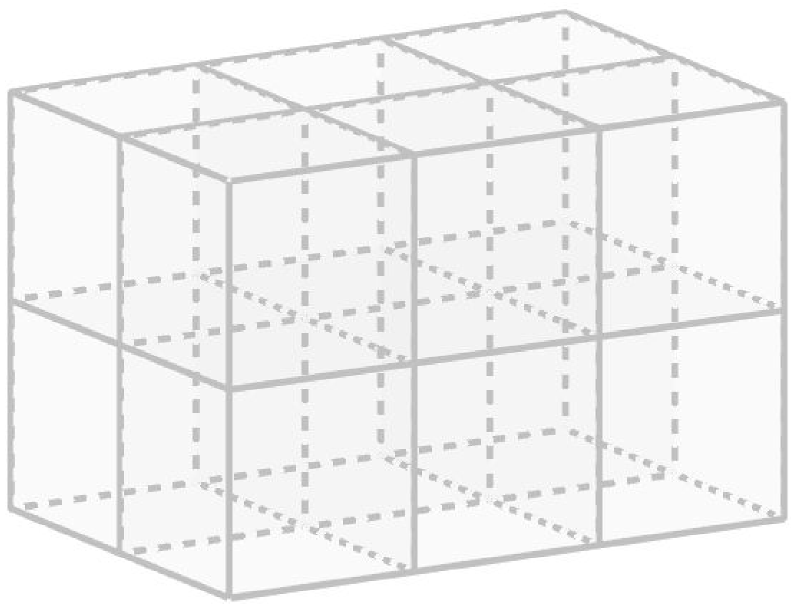
What is Density?

In the last section, you read about matter, mass and volume. Density is a relationship between the amount of matter (also known as the mass) and the volume of an object. Let's see how density works.

The Mass of a Cube

Answer the questions below. Check your answers in What is Density? - Answer Key.

1) Look at the stack of cubes below. How many cubes do you see? __________



2) Each of the cubes measures 1 inch on a side. The volume of the full stack is __________ cubic inches.

3) Imagine that each cube in the stack weighs 2 ounces. What would be the mass of the whole stack of cubes? __________ ounces.

4) Imagine each cube weighs 3 ounces. What would be the mass of the whole stack? __________ ounces.

Complete the table.

	mass of each 1-inch cube	mass of whole stack
5)	1 ounce	12 ounces
6)	2 ounces	24 ounces
7)	3 ounces	
8)	4 ounces	
9)	5 ounces	

	mass of each 1-inch cube	mass of whole stack
10)	6 ounces	
11)	7 ounces	
12)	8 ounces	
13)	9 ounces	
14)	10 ounces	

Now imagine that each of the 1-inch cubes in the stack is made of copper, which is a kind of metal.

15) If the mass of all 12 of the copper cubes measured together equals 60 ounces, what would be the mass of one copper cube? How do you know?

There are different ways to figure out the mass of one copper cube. Maybe you looked at the table above and saw that if the individual cubes weigh 5 ounces each, then the full stack of 12 cubic inches would weigh 60 ounces. Or you may have divided the mass of the full stack (60 ounces) by the number of cubes (12) to get 5 ounces per[1] cube.

The mass of one cube is the same as the density of the substance. A 1-inch cube of copper weighs 5 ounces, so copper has a density of 5 ounces per cubic inch. In the American system, ounces are a measure of mass and cubic inches are a measure of volume.

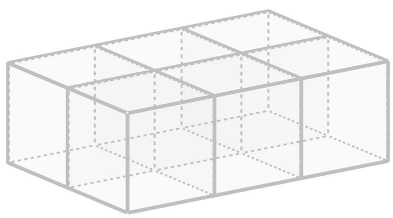
[1] *Per* means "for every." 5 ounces per cube means that each cube weighs 5 ounces. 60 miles per hour means that you are traveling 60 miles for every hour you travel. $2.00 dollars per pound means you will pay $2.00 for every pound you buy. See **Population Density** for more practice with *per*.

In the metric system, people use cubic centimeters to measure volume and grams to measure mass. 9 grams per cubic centimeter is a metric measurement for the density of copper. This means that every 1-centimeter cube of copper weighs 9 grams.

See if you can figure out the density of the two mystery substances below.

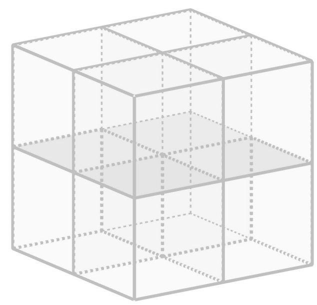
16) Stack A and Stack B are made from 1-centimeter cubes, but the cubes are made from two different substances.

Stack A



Substance A
total weight is 54 grams

Stack B



Substance B
total weight is 56 grams

Which stack has a larger volume? ______________________________

Which stack has a larger mass? ________________________________

Which substance has a larger density? ___________________________

Explain your answers below.

Density is a Physical Property

Scientists define density as the mass of a substance per unit volume. This is another way of saying that density is the weight of one cubic unit of the substance. Density is the relationship between the mass of one unit of a material and the volume of that one unit.

In science, density is considered a *physical property* of matter. A physical property is something you can observe by examining a substance. Other physical properties include the substance's color, its odor, how hard it is, at what temperature it boils and at what temperature it freezes.

If you cut a bar of silver in half, you would have two bars with half the mass of the original bar. However, each bar would also have half the volume of the original bar. The density of silver does not change. The density of a substance does not depend on how much of it you have. Physical properties do not change with the amount or shape of the substance, and are therefore useful in identifying unknown substances.

17) Scientists often figure out what a substance is by examining its physical properties. Imagine that you find an object on the ground and want to know what it is.

    The object has the following physical properties:

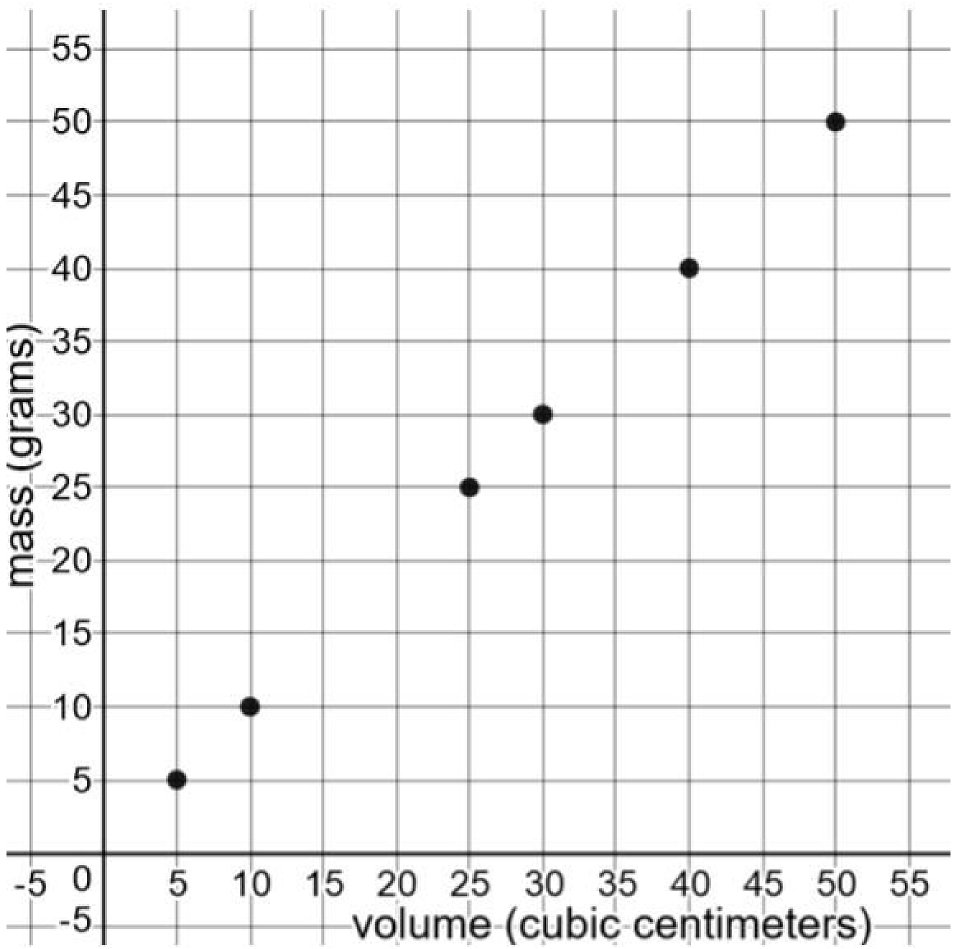
- Smooth
- Metallic surface
- Yellow-brown color
- Hard enough that you can't scratch it with your fingernail
- Soft enough that you can dent it with a hammer
- Weighs about 19 grams per cubic centimeter

    What do you think the object is made of?

We'll be looking at the density of different substances, such as water, ice, salt, and silver.

A scientist measured six water samples and entered the data into the chart below.

Volume and Mass of Water



18) Look at the chart above. What do you notice about the data points?

- ➢
- ➢
- ➢

The table below shows the same data as the graph on the previous page.

Volume and Mass of Water	
Volume (cm^3)	**Mass (g)**
5	5
10	10
25	25
30	30
40	40
50	50

Reminder: *The abbreviation* ***cm^3*** *means cubic centimeters and* ***g*** *means grams.*

19) What do you notice when you look at this chart? ______________________________

____

20) What would be the mass of 35 cm^3 of water? ________________________________

21) What would you expect the mass of 500 cm^3 of water to be? Why? ____________

____

22) What would be the mass of 1 cm^3 of water?

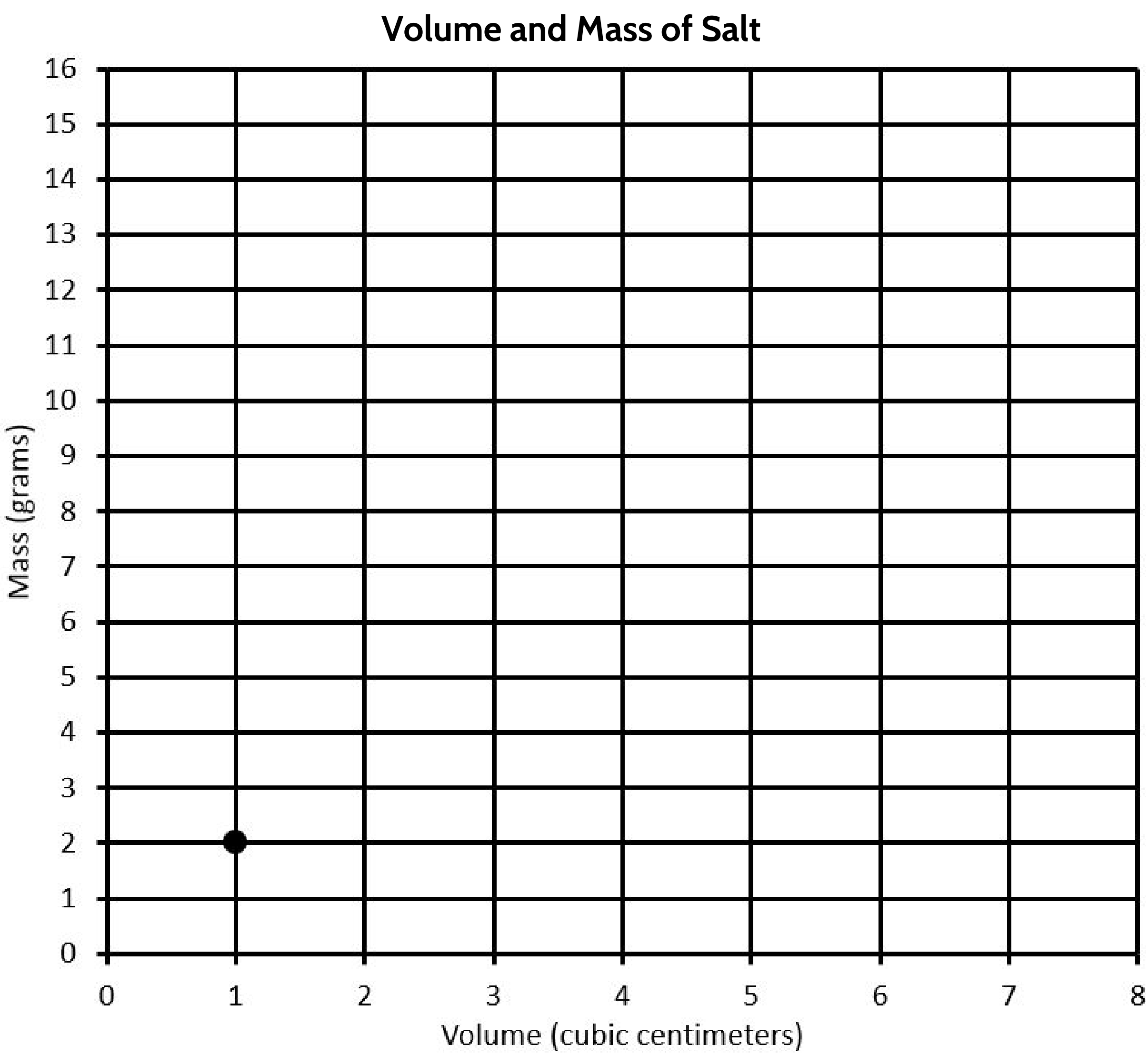
____

23) What is the density of water? ____

The information above is based on a physical property of water. Water has a density of 1 gram per cubic centimeter, which means that each cubic centimeter of water weighs 1 gram.

With a density of about 2 grams per cubic centimeter, table salt has a higher density than water. This means that if you put a 1-centimeter cube of salt on a scale, it would weigh about 2 grams.

24) Fill in the missing blanks in the table and then add the points on the graph.



Volume (cm^3)	1	2	3	4	5	6	7
Mass (g)	2						

Complete the table. You can check your answers in the Science and the Density of Matter - Answer Key.

	Substance	Density (grams per cm^3)	2 cm^3 of the substance would weigh...	5 cm^3 of the substance would weigh...	10 cm^3 of the substance would weigh...
25)	salt	2 g/cm^3	4 grams	10 grams	20 grams
26)	water	1 g/cm^3			
27)	copper	9 g/cm^3			
28)	gold	19 g/cm^3			
29)	concrete	2.25 g/cm^3			
30)	soap	.9 g/cm^3			
31)	feathers	0.0025 g/cm^3			
32)	silver	_____ g/cm^3	20 grams	50 grams	100 grams
33)	nickel*	_____ g/cm^3	18 grams	45 grams	90 grams

* Nickel is a type of metal. The coins we call "nickels" are made from 25% nickel and 75% copper.

Does It Sink or Float?

Anything that sinks in water has a higher density than water. If you put a quarter in a glass of water, it will sink. Quarters are made from an alloy (a mixture of metals) of 92 percent copper and 8 percent nickel. Both copper and nickel have a density of about 9 g/cm^3. The alloy has a higher density than water, so it sinks.

34) What are some everyday objects that sink in water? You might give it a try, but don't put your phone underwater.☺

Quarter , ____________ , ____________ , ____________ , ____________

How do know if something has a lower density than water? Anything that floats in water has a lower density. If you put a bar of soap in water, it will float. Styrofoam, for example, will float in water because it is lighter for its size.

35) What are some materials that float in water?

Styrofoam , ____________ , ____________ , ____________ , ____________

Whether an object floats or sinks is related to its density, not its mass (weight). A cork weighing 12.5 grams floats on water, while a piece of lead weighing 2.5 grams sinks to the bottom. The cork is heavier, but it floats while the lighter piece of lead sinks to the bottom.

By the way, there many different ways to write the density of a material. All of these abbreviations mean "2 grams per cubic centimeter:"

2 grams/cubic centimeter *2 g/cm^3* *2 grams/cu. cm.* *2 g/cc*

orange slices

pineapple slices
(top and bottom)

cucumber slices (top)
lime slices (bottom)

36) Looking at this photograph, what can you say about the fruits and vegetables listed?

What is Density? - Answer Key

1) There are 12 cubes.

2) Each cube is 1 inch on a side, so the volume of the stack is 12 cubic inches.

3) 24 ounces

4) 36 ounces

5) 12 ounces

6) 24 ounces

7) 36 ounces

8) 48 ounces

9) 60 ounces

10) 72 ounces

11) 84 ounces

12) 96 ounces

13) 108 ounces

14) 120 ounces

15) 5 ounces. You can see this in the table you completed above or you could divide 60 by 12 to get 5.

16) Stack B has a higher volume (8 cubic centimeters). Substance B has a higher mass (56 grams). Substance A is more dense. In your explanation, you might calculate the density of each substance. The density of Substance A is 9 grams per cubic centimeter. The density of Substance B is 7 grams per cubic centimeter. Each Substance A cube weighs more, so we would say it has a higher density. Stack B has a larger weight overall, but each individual cube is lighter.

17) The object you found on the ground is made out of gold! Any piece of pure 24-karat gold will have these physical properties.

18) There are lots of things you might notice:

- Each of the numbers go up by 5.
- One sample was 5 grams in mass and 5 grams in volume.
- Another sample was 10 grams in mass and 10 grams in volume.
- If you connected the dots, it would make a straight line.

19) The volume and the mass is the same for each sample.

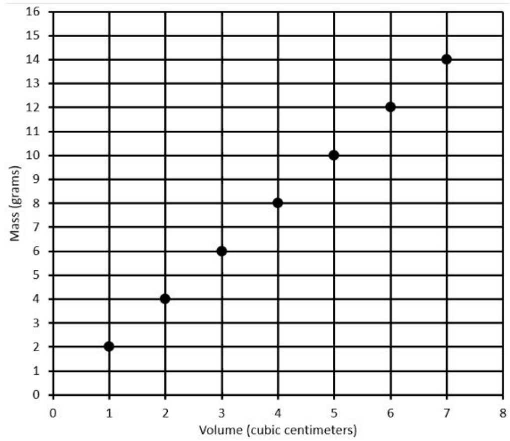
20) 35 grams

21) 500 grams. The number of grams is the same as the number of ounces.

22) 1 gram

23) 1 gram per cubic centimeter

24)



Volume (cm^3)	1	2	3	4	5	6	7
Mass (g)	2	4	6	8	10	12	14

25) Salt: 2 g/cm^3, 4 grams, 10 grams, 20 grams

26) Water: 1 g/cm^3, 2 grams, 5 grams, 10 grams

27) Copper: 9 g/cm^3, 18 g/cm^3, 45 g/cm^3, 90 g/cm^3

28) Gold: 19 g/cm^3, 38 grams, 95 grams, 190 grams

29) Concrete: 2.25 g/cm^3, 4.5 grams, 11.25 grams, 22.5 grams

30) Soap: .9 g/cm^3, 1.8 grams, 4.5 grams, 9 grams (This is the density of a bar of ivory soap, by the way. A bar of soap weighs 113 grams. Can you figure out the volume of a bar of soap?)

31) Feathers: 0.0025 g/cm^3, 0.0050 grams, 0.0125 grams, 0.025 grams

32) Silver: 10 g/cm^3

33) Nickel: 9 g/cm^3

34) Anything that has a higher density than water will sink. Examples include: sand, rocks, metal, and honey. All of these substances have a density that is more than 1 gram per cubic centimeter.

35) Anything that has a lower density than water will float. Examples include: most types of wood, ice, butter, and cooking oil. All have a density that is less than 1 gram per cubic centimeter.

36) Thanks to Sendhil Revuluri, @revuluri:

Reviewing What We Have Learned about the Density of Matter

The density of a substance tells you how heavy it is for its size. It shows the relationship between the mass and the volume. Let's compare a metal fork made of steel and a plastic fork made of polystyrene. A cubic centimeter of steel weighs about 8 grams. A cubic centimeter of polystyrene plastic weighs about 1 gram. Steel is heavier for its size and therefore has a higher density than plastic.

The density of water is 1 gram per cubic centimeter. The density of other substances is compared against the density of water. If a substance has a density higher that 1 g/cm^3, it will sink in water. If it has a density lower than 1 g/cm^3, it will float in water.

If you know the mass and volume of an object, you can determine its density. For example, if you know that a silver chain weighs 40 grams and has a volume of 4 cubic centimeters, you can figure out the density of the silver in the chain. Each cubic centimeter of silver must weigh 10 grams.

We could also divide the total mass by the total volume to find the density of a material.

***40 grams** divided by **4 cubic centimeters** equals **10 grams per cubic centimeter**.*

Which can be written as:

mass** divided by **volume** equals **density

You can write this as a formula:

$$\frac{mass}{volume} = density$$

or abbreviate it as:

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

If you insert numbers, you get:

$$\frac{40 \text{ grams}}{4 \text{ cm}^3} = 10 \text{ grams/cm}^3$$

This means "grams per cubic centimeter."

This means 40 divided by 4. The horizontal line means the top number is divided by the bottom number, so the whole equation means 40 ÷ 4 = 10.

Other Ways to Use the Density Formula

In the example above, we used the mass and the volume to find the density. In some situations, you might know the density, but not know one of the other amounts.

For example, if you know the mass and the density, you can use them to find the volume.

1) A silver ring weighs 5 grams. The density of silver is about 10 grams per cubic centimeter. What is the volume of the ring? How do you know?

If you know the density and the volume, you can use them to find the mass.

2) Iron weighs about 8 grams per cubic centimeter. If you have 7 cubic centimeters of iron, how much would it weigh? How do you know?

3) Which would take up more space, a pound of feathers or a pound of lead?

   Which would be heavier, a cubic foot of feathers or a cubic foot of lead?

What Happens When We Change Just the Mass or the Volume?

Using the density formula, let's see how changing the mass or volume affects the density. On this page, the goal is to learn what happens when we change numbers in the formula, so don't worry about using units for mass or volume.

Use the formula below and a calculator to find the missing densities in both tables. Round to the nearest hundredth place.

$$\frac{mass}{volume} = density$$

What happens when the mass changes and the volume stays the same?

mass	volume	density
10	50	0.2
20	50	
30	50	
40	50	
50	50	
60	50	
70	50	
80	50	
90	50	
100	50	

What happens when the volume changes and the mass stays the same?

mass	volume	density
50	10	5.00
50	20	
50	30	
50	40	
50	50	
50	60	
50	70	
50	80	
50	90	
50	100	

4) If the mass goes up and the volume stays the same, the density **increases / decreases / stays the same**. *(circle one)*

5) If the mass goes down and the volume stays the same, the density **increases / decreases / stays the same**. *(circle one)*

6) If the volume goes up and the mass stays the same, the density **increases / decreases / stays the same**. *(circle one)*

7) If the volume goes down and the mass stays the same, the density **increases / decreases / stays the same**. *(circle one)*

8) If two objects have the same mass but different volumes

   A. The one with the larger volume has the lower density
   B. They must have the same density
   C. The one with the larger volume has the higher density
   D. The one with the larger volume is twice as dense

9) If two objects have the same volume but different mass

   A. The one with the larger mass has the lower density
   B. They must have the same density
   C. The one with the larger mass has the higher density
   D. The one with the larger mass is twice as dense

10) If you cut a wooden block in half, each half would have

   A. Half the density of the original piece
   B. Twice the density of the original piece
   C. The same density as the original piece
   D. No density at all

Reviewing What We Have Learned - Answer Key

1) The volume of the ring is ½ cubic centimeter. Each cubic centimeter is 10 grams, so half of a cubic centimeter is 5 grams. If you know the mass and the density, you can find out the volume by dividing the population by the density: $\frac{m}{d} = v$

   Here's another example for you to try:

   > *A gold chain weighs 57 grams. The density of gold is about 19 grams per cubic centimeter. What is the volume of the ring?*

2) The mass of the iron is 56 grams. If you know the volume and the density, you can find out the mass by multiplying the volume by the density: $v \times d = m$

   Here's another example to try:

   > *Pine wood weighs about 25 pounds per cubic foot. If you have 3 cubic feet of pine, how much would it weigh?*

3) A pound of feathers would take up a lot more space than a pound of lead because feathers are much less dense. You would need a lot of feathers to make the same amount of weight.

   A cubic foot of lead would be much heavier than a cubic foot of feathers. A cubic foot of feathers weighs about as much as a pillow. A cubic foot of lead weighs almost 700 pounds!

4) If the mass goes up and the volume stays the same, the density increases.

5) If the mass goes down and the volume stays the same, the density decreases.

6) If the volume goes up and the mass stays the same, the density decreases.

7) If the volume goes down and the mass stays the same, the density increases.

8) A

9) C

10) C

The Metric System

Estimating Measurements

Since scientists use the metric system, they usually measure density in grams per cubic centimeter. In order to get an idea of what these measurements mean, look at the following rules of thumb:

- The width of an average fingernail is about 1 centimeter.
- A large paperclip weighs 1 gram.
- A die is about 3 ½ cubic centimeters.

1 centimeter

1 gram

3 ½ cubic centimeters

Look for objects around you to answer the following questions. You can compare your answers in the Measuring with the Metric System - Answer Key.

1) What is something that is about 15 centimeters long? ___________________________

2) What is something that weighs about 5 grams? ________________________________

3) What is something that is about 15 cubic centimeters in size? ____________________

Prefixes in the Metric System

Meters and grams are examples of metric units. We have been using centimeters to measure length. You may have also heard of kilometers for measuring long distances. In the metric system, a prefix (something added to the beginning of a word) is used to change the size of a measurement. For example, the prefix "kilo" means one thousand. When you add "kilo" to the beginning of a metric unit, it's like multiplying the unit by 1,000. A kilogram is 1,000 grams. A kilogram is 1,000 times bigger than a gram.

On the other hand, the prefix “milli” means one thousandth ($\frac{1}{1000}$). For example, a millimeter is one thousandth of a meter. This means there are 1,000 millimeters in a meter. There are also 1,000 milligrams in a gram. A milligram is 1,000 times smaller than a gram.

“Centi” is another example of a prefix used in the metric system. It means one hundredth ($\frac{1}{100}$). Centi comes from the Latin word centum, meaning "hundred." English words such as cent, century, and percent also refer to one hundred. A centimeter is $\frac{1}{100}$ of a meter, which means that there are 100 centimeters in 1 meter.

Here are some common prefixes in the metric system:

Prefix	English word	In numerals
tera	trillion	1,000,000,000,000
giga	billion	1,000,000,000
mega	million	1,000,000
kilo	thousand	1,000
hecto	hundred	100
deca	ten	10
deci	tenth	$\frac{1}{10}$ or 0.1
centi	hundredth	$\frac{1}{100}$ or 0.01
milli	thousandth	$\frac{1}{1000}$ or 0.001

Answer the following questions.

4) In computers, cell phones and tablets, stored information is measured in bytes. A byte is a very small amount of information, so we usually measure how much devices can store in kilobytes (kB), megabytes (MB), gigabytes (GB) and even terabytes (TB).

   Look at a cell phone. How much storage does it have? ____________________________

5) How many bytes are there in kilobyte? _______________

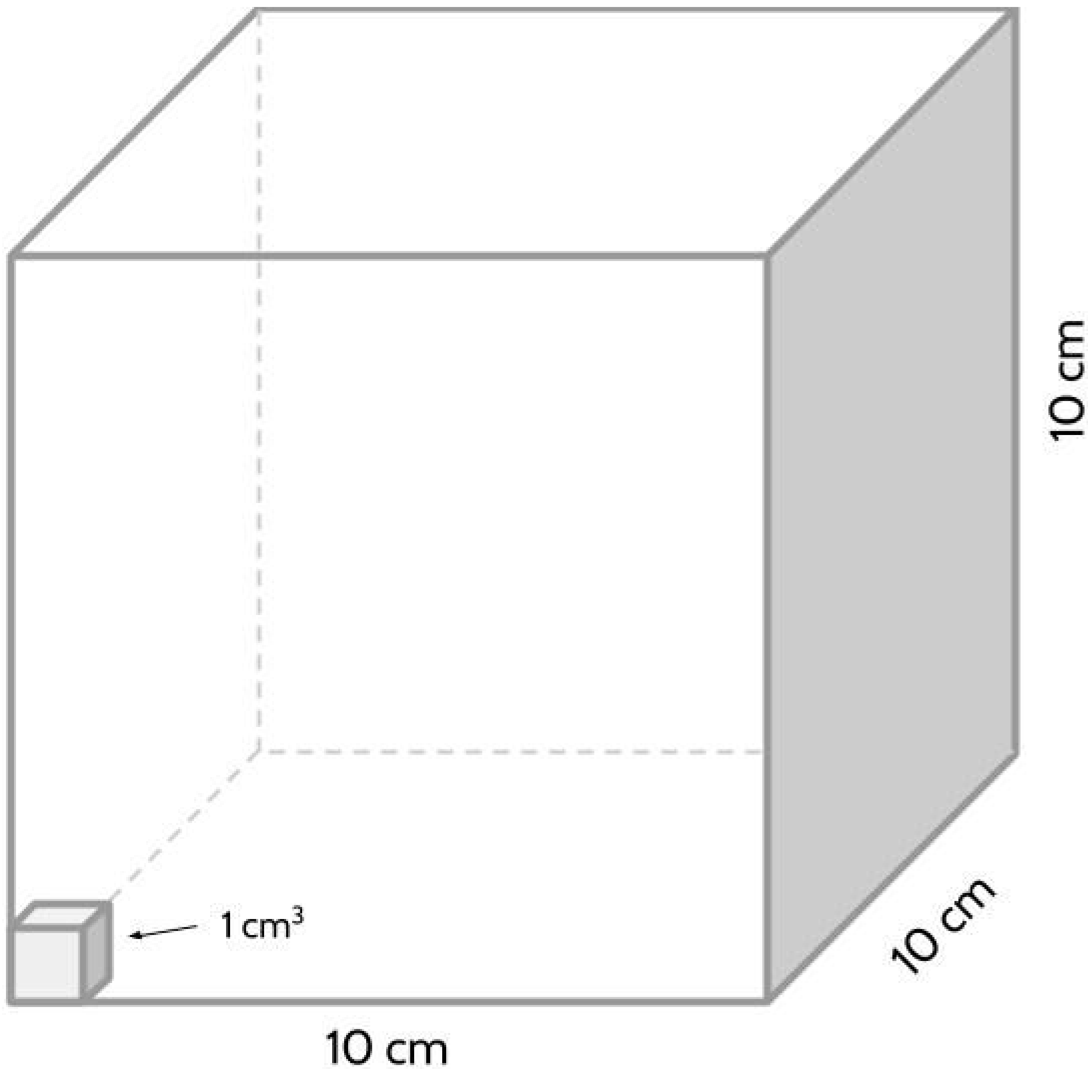
6) How many bytes are there in 5 megabytes? _______________

7) How many meters are in a 10 kilometers? _______________

8) How many milliliters are in a ½ liter? _______________

As you know, cubic centimeters are a measurement of volume. You can also use *liters* to measure the volume of liquids. Water, alcohol, hand soap, motor oil, and other liquids are sold in 1-liter bottles.

A liter is defined as the volume of a cube that is 10 centimeters on each side.



9) What is the volume of a liter measured in cubic centimeters? ___________________
(In other words, how many 1-centimeter cubes fit in a 10cm × 10cm × 10cm cube?)

Explain your answer.

Cubic Centimeters and Milliliters

We have been using cubic centimeters to measure volume and calculate density. A cubic centimeter of water is actually exactly equal to 1 milliliter. Since a milliliter and a cubic centimeter are equal, there are 1,000 cm^3 in a liter. If you buy a 1-liter bottle of soda, you're actually buying 1,000 cubic centimeters of soda!

10) How many milliliters are equal to 700 cubic centimeters? _______________

11) What is the volume of a 2-liter bottle in cubic centimeters? _______________

Milliliters are commonly used in health care. If you're measuring liquid medicine, you may need to measure in milliliters (mL) or cubic centimeters (cc).

In cooking, a teaspoon is a measuring spoon that is the same volume as 5 milliliters or 5 cubic centimeters. A tablespoon is the same as 3 teaspoons. Milliliters, teaspoons, and tablespoons are also measures of volume.

Fill in the missing blanks.

	Cubic Centimeters	Milliliters	Teaspoons	Tablespoons
12)	5		1	$\frac{1}{3}$
13)	10			
14)	15			
15)	20			

16) How many milliliters are in 2 tablespoons? _______________

Since a cubic centimeter and a milliliter are equivalent (the same size), you might see density measurements written as grams per cubic centimeter (g/cm^3) or grams per milliliter (g/ml). These two measurements mean the same thing. Since water has a density of 1 gram per cubic centimeter, you could also say that the density of water is 1 g/ml. Liters and milliliters are usually used only for measuring volume of liquids or gas. If you are measuring the volume of something solid, you would use cubic centimeters instead.

The size of car and motorcycle engines is also measured in cubic centimeters or liters. The volume (or capacity) of the engine cylinders is bigger in more powerful vehicles.

Fill in the missing blanks.

		Engine Capacity	
	Car	**Cubic Centimeters**	**Liters**
17)	Honda Accord	1500	1.5
18)	Ford Explorer		3.5
19)	Audi Q5	2000	
20)	Smart Fortwo		.7

		Engine Capacity	
	Motorcycle	**Cubic Centimeters**	**Liters**
21)	Kawasaki Z900RS	950	.95
22)	Yamaha YZF-R3	300	
23)	Royal Enfield Continental GT		.65
24)	Triumph Thunderbird Storm	1700	

25) You can convert liters to cm^3 by __________________ the number of liters by 1,000.

A. adding
B. subtracting
C. multiplying
D. dividing

26) You can convert cm^3 to liters by __________________ the number of cm^3 by 1,000.

A. adding
B. subtracting
C. multiplying
D. dividing

Measuring with the Metric System - Answer Key

1) There are many possible answers. Pens and pencils are about 15 centimeters long.
2) There are many possible answers. Quarters weigh about 5 1/2 grams.
3) There are many possible answers. A tablespoon of butter is about 15 cubic centimeters.
4) Different phones have different amounts of storage. Currently, some common sizes are 16, 32 or 64 gigabytes.
5) 1,000
6) 5,000,000
7) 10,000
8) 500
9) 1,000
10) 700
11) 2,000
12) 5, 1, $\frac{1}{3}$
13) 10, 2, $\frac{2}{3}$
14) 15, 3, $\frac{3}{3}$ or 1
15) 20, 4, $\frac{4}{3}$ or $1\frac{1}{3}$
16) 30
17) 1500, 1.5
18) 3500, 3.5
19) 2000, 2
20) 700, 7
21) 950, .95
22) 300, .3
23) 650, .65
24) 1700, 1.7
25) C
26) D

Indiana Jones and the Golden Statue

In the famous opening scene of the movie *Raiders of the Lost Ark*, the character Indiana Jones steals a golden statue by replacing it with a bag of sand. After he switches the two objects, the cave starts to self-destruct and he runs out with the statue, barely escaping a huge rolling stone. In this section, you are going to fact-check the film using your knowledge of density.

Jones replaces the golden statue with a bag of sand.

If possible, watch the scene (http://bit.ly/indianaclip), then answer the questions below. You can check your answers in The Density of Gold - Answer Key.

1) Why does Indiana Jones replace the statue with a bag of sand?

2) Is the scene believable to you? Why or why not?

3) After Indiana Jones replaces the statue with the bag of sand, the cave starts to self-destruct. Why do you think that happens?

The base of the statue is rigged with a booby trap based on the weight of the statue. Jones is trying to replace the statue with a bag of sand that is the same weight as the statue. The bag of sand and the gold statue look like they are about the same size, right?

bag of sand

gold statue

4) The important thing is that the two objects have to weigh the same amount. What do you think? Explain your answer.

In order to find out the mass of the two objects, we need to use the density of sand and the density of gold. We already know that the density of gold is about 19 grams per cubic centimeter. More precisely, it is 19.3 g/cm^3. The density of sand is about 2.5 g/cm^3.

5) Assuming the statue is solid gold, do you think the bag of sand and the gold statue could weigh the same amount? Explain.

Then we need to make an estimate of the volume of the bag of sand and the volume of the statue.

6) Let's estimate the volume of the gold statue. If it were in the shape of a rectangular prism (like a box), we might guess that it is about 16 cm tall, 12 cm wide and 8 cm deep. What is the approximate volume of the statue in cubic centimeters?

7) Compare the size of the gold statue with a 1-liter bottle of soda. Is it bigger or smaller that the bottle? How much bigger or smaller?

8) Every cubic centimeter of gold weighs ________ grams because the density of gold is 19.3 g/cm^3.

9) Use the density of gold to calculate the weight of the statue in grams.

10) About how many kilograms is this? _____________ (Round to the nearest kilogram.)

11) Now, let's estimate the volume of the bag of sand. If it were in the shape of a rectangular prism, we might guess that it would fill a space that is 10 cm tall, 10 cm wide and 15 cm long. What is the approximate volume of the bag of sand in cm^3?

12) Every cubic centimeter of sand weighs ________ grams because the density of sand is 2.5 g/cm^3.

13) Use the density of sand to estimate the weight of the bag of sand in grams.

14) About how many kilograms is this? _____________ (Round to the nearest kilogram.)

15) Compare the weight of the bag of sand and the statue? What do you notice?

By now, you should know the weight of the statue and the bag of sand in grams and kilograms. Since most Americans are more familiar with pounds for measuring weight, we will convert kilograms to pounds to get a feel for how much the objects weigh.

There are about 2.2 pounds in a kilogram. You could also write this as 1 kg = 2.2 lb, since *kg* is abbreviation for kilograms and *lb* is an abbreviation for pounds.

Knowing that 1 kilogram is equivalent to 2.2 pounds, let's see if we can convert the weight of the statue and the bag of sand to pounds. Fill in the blanks in the table below.

	kg	lb
16)	1	2.2
17)	2	
18)	3	
19)	4	
20)	5	

	kg	lb
21)	10	
22)	15	
23)	20	
24)	25	
25)	30	

26) What is the approximate mass of the statue in pounds?

To convert from kilograms to pounds, you use a table like the one above or you can multiply the number of kilograms by the number of pounds. For example, 5 kg × 2.2 lb/kg = 11 lb.

27) What is the mass of the bag of sand in pounds?

28) While running away, Indiana Jones throws the statue to his accomplice who catches it easily. Does this seem realistic to you? Why or why not?

volume of the statue in cm^3

mass of the statue in grams

mass of the bag of sand in grams

mass of the statue in pounds

mass of the statue in kg

mass of the bag of sand in pounds

volume of the bag of sand in cm^3

mass of the bag of sand in kg

Find the answer to the calculations below, then write the purpose of each calculation, choosing from the descriptions above. The first one is done for you.

Example: $10 \times 10 \times 15 =$ 1500 → volume of the bag of sand in cm^3

29) $16 \times 12 \times 8 =$ _______ → ____

30) $\frac{29{,}644.8}{1{,}000} =$ _______ → ____

31) $\frac{(16\times12\times8)\times19.3}{1000} \times 2.2 =$ _______ → ________________________________

32) $(10 \times 10 \times 15) \times 2.5 =$ _______ → ________________________________

33) $\frac{(10\times10\times15)\times2.5}{1000} \times 2.2 =$ _______ → ________________________________

34) $(16 \times 12 \times 8) \times 19.3 =$ _______ → ________________________________

35) $\frac{3{,}750}{1{,}000} =$ _______ → ____

Indiana Jones and the Golden Statue - Answer Key

1) So that he can steal the golden statue without anyone knowing. And so that it doesn't set off the booby trap.
2) What do you think?
3) We want to know what you think.
4) It's still up to you.
5) If the two objects are about the same size, they can't also be the same weight because the density of sand is much less than gold.
6) 1,536 cm^3
7) 1 liter is 1,000 cm^3. The statue is about 1 ½ times bigger than a liter.
8) 19.3 grams
9) 29,644.8 grams
10) 30 kg (It would be exactly 29.6448 kg based on the volume calculation.)
11) 1,500 cm^3
12) 2.5 grams
13) 3,750 grams
14) 4 kg (It would be exactly 3.75 kg based on the volume calculation.)
15) The statue is about 26 kg heavier than the bag of sand. It is more than 7 times heavier than the bag of sand.
16) 2.2
17) 4.4
18) 6.6
19) 8.8
20) 11
21) 22
22) 33
23) 44
24) 55
25) 66
26) If you use the table, you can see that 30 kg = 66 pounds. You might also multiply the exact number of kg (29.6448 kg × 2.2 kg/lb = 65.21856 lb). Your answer depends on whether you use the rounded or exact number of kilograms.
27) 8.25 pounds (3.75 kg × 2.2 kg/lb) or 8.8 pounds (4 kg × 2.2 kg/lb). Your answer depends on whether you use the rounded or exact number of kilograms.
28) We want to know what you think.
29) volume of the statue in cm^3
30) mass of the statue in kg
31) mass of the statue in pounds
32) mass of the bag of sand in grams
33) mass of the bag of sand in pounds
34) mass of the statue in grams
35) mass of the bag of sand in kg

Density of Common Substances

Wood

If you buy boards at a hardware store or lumberyard, they will probably be made of pine. In construction, pine is commonly used.

Look at the chart below which shows different volumes of pine and the mass of each sample, then answer the questions that follow.

Volume of Wood (cubic feet)	Mass (pounds)
3	75
5	125
8	200
10	250

1) How much does 6 cubic feet of pine weigh? ____________

2) How much does 9 cubic feet of pine weigh? ____________

3) How much does 1 cubic feet of pine weigh? ____________

   (Another way of saying this is: The density of pine is ____________ lb/ft^3.)

4) How much does 2 cubic feet of pine weigh? ____________

5) How much does 15 cubic feet of pine weigh? ____________

6) How much does 1 ½ cubic feet of pine weigh? ____________

7) Which of the following functions would give you the weight of a sample of pine if you knew the volume?

   A. $y = 25x$

   B. $y = \frac{x}{25}$

   C. $y = \frac{1}{25}x$

   D. $y = x + 25$

8) Which of the following calculations will give you the density of pine? You can choose more than one.

   A. 75 ÷ 3

   B. 3 ÷ 75

   C. 125 ÷ 5

   D. 5 ÷ 125

   E. 250 ÷ 10

   F. 200 ÷ 8

9) Imagine you are building a garage that will require 500 cubic feet of pine.

   A. How much would the total wood weigh?

   B. If the pine costs $7.50 per cubic foot, how much would it cost to buy all the wood for the garage?

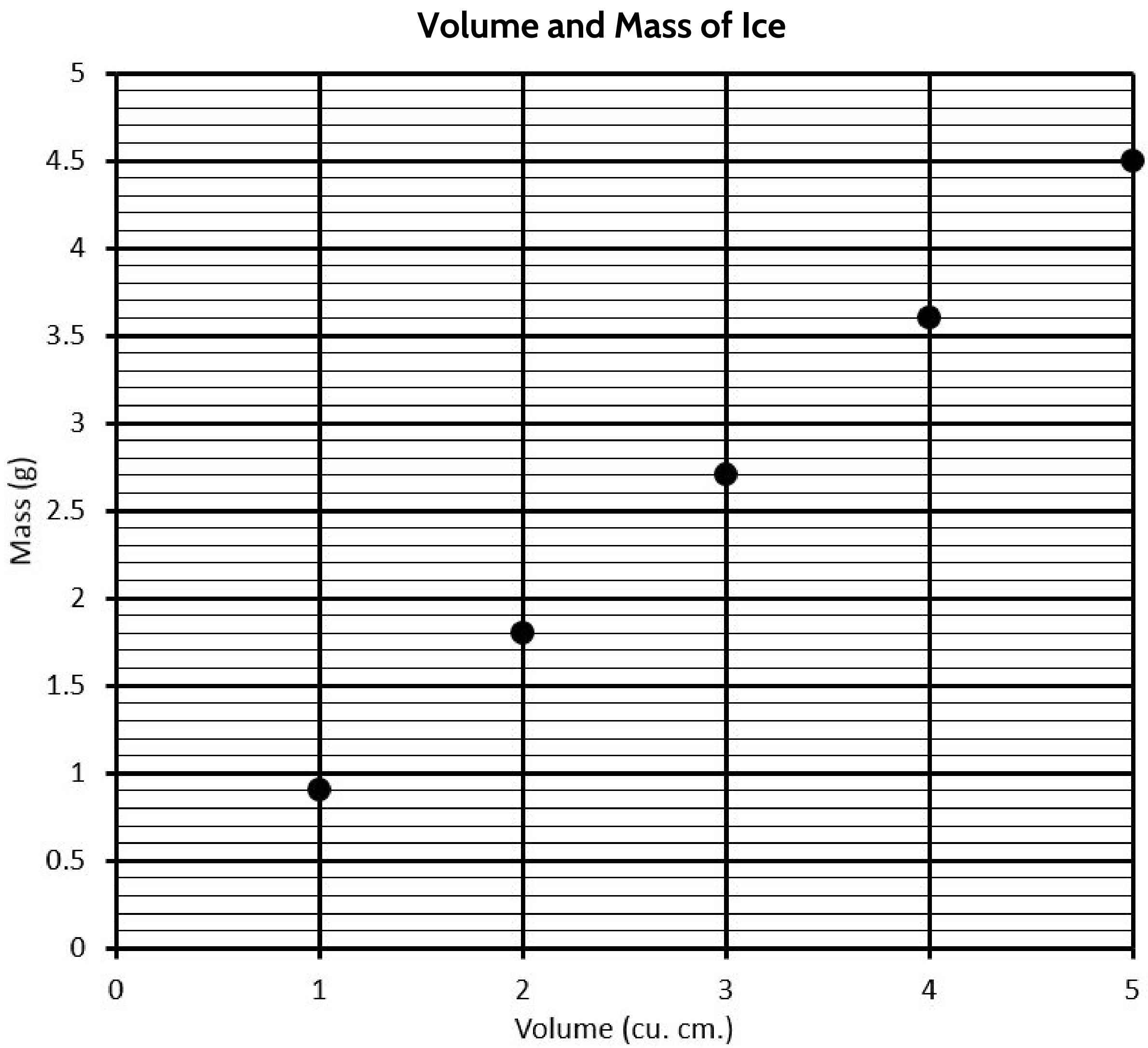
Ice

If you put a few ice cubes in a glass and then fill it with water, what happens to the ice cubes? Do they float or sink? If you're able to, give it a try before moving on.

10) What did you find out?

____

Look over this chart.



11) What do you notice when looking at the chart on the previous page?

Using the chart on the previous page, fill in the missing blanks in this table of data.

	Volume and Mass of Ice	
	Volume (cu. cm)	**Mass (g)**
12)	0	
13)	1	
14)	2	
15)	3	2.7
16)	4	
17)	5	

18) What would the mass be for 10 cm^3 of ice? ___________________________________

19) Based on this data, what is the density of ice? ___________________________________

20) You may have noticed that water expands when it freezes into ice. You can see that water in ice trays expands when frozen. A bottle of water might even explode if you fill it completely and put it in the freezer. Be careful if you try this at home!

As you showed above, the density of ice is not the same as the density of liquid water. Why do you think the density is different?

21) Why does ice float in water?

Interestingly, most substances expand when they heat up and shrink as they get colder. If you have a jar that is hard to open, running hot water over a metal lid will make the metal expand and make it easier to open the jar. When metal gets cold, it shrinks a little bit.

The behaviour of water is different, though. When water freezes, it expands. Because water gets bigger when it freezes, its density goes down.

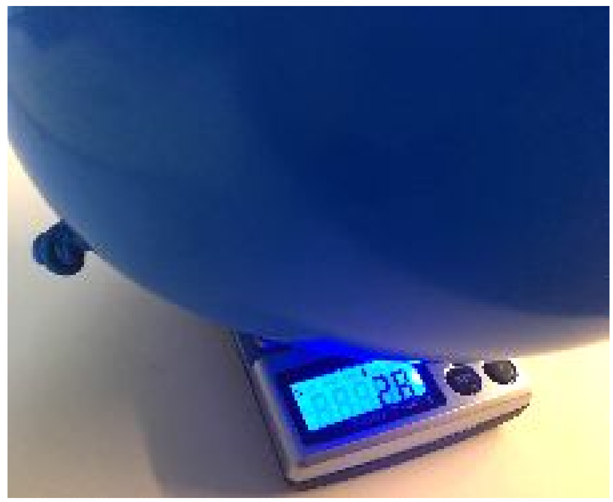
22) When water turns to ice, the volume gets bigger and the mass stays the same. Why does that make the density go down?

Ice floats in water because it is lighter than liquid water. Ice weighs .9 grams per cubic centimeter and water weighs 1 gram per cubic centimeter, so the water sinks to the bottom and the ice floats to the top.

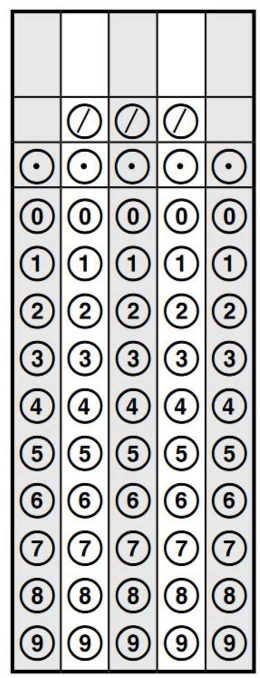
Think about a frozen lake. The ice is on top of cold liquid water below. Most lakes don't freeze completely solid, so the ice is on top of water. The ice floats on top of the water because it has a lower density than the liquid water in the pond. If ice were heavier than water, it would be on the bottom of the lake under the water.

Air

The air we breathe is made up of nitrogen, oxygen, carbon dioxide and other gases. Though it may be surprising to hear, air is matter. Here is a way to demonstrate that this is true. Take a balloon and blow up it up with air. It definitely has volume because it takes up space. In fact, it takes up more space when it's full of air, so the air inside must have volume. To show that air has mass, you can weigh an empty balloon and compare the weight to a balloon that is full of air.



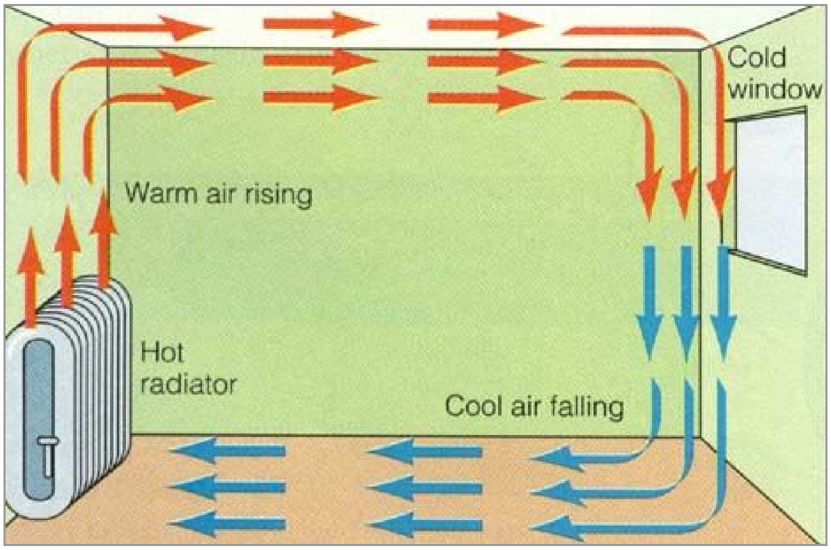
23) As you can see, the weight of the empty balloon is 2.6 grams and the weight of the full balloon is 2.8 grams, so the air inside the full balloon must weigh __________ grams! *Enter your answer in the grid.*



If you imagine a larger volume of air, like the air in a room, it would have a lot more mass. If you think about the mass of air in a football stadium or even in all of Earth's atmosphere, you can imagine that the mass of an amount of air can be really large.

Because air has mass and volume, it also has a density. The density of air depends on its temperature. As you read previously, substances tend to expand when they heat up and shrink when they cool down. Air does this as well. As air warms up, its volume increases and its density goes down. As air cools off, its volume decreases and its density goes up.

Look at the image on the next page.



24) What do you see happening in this diagram?

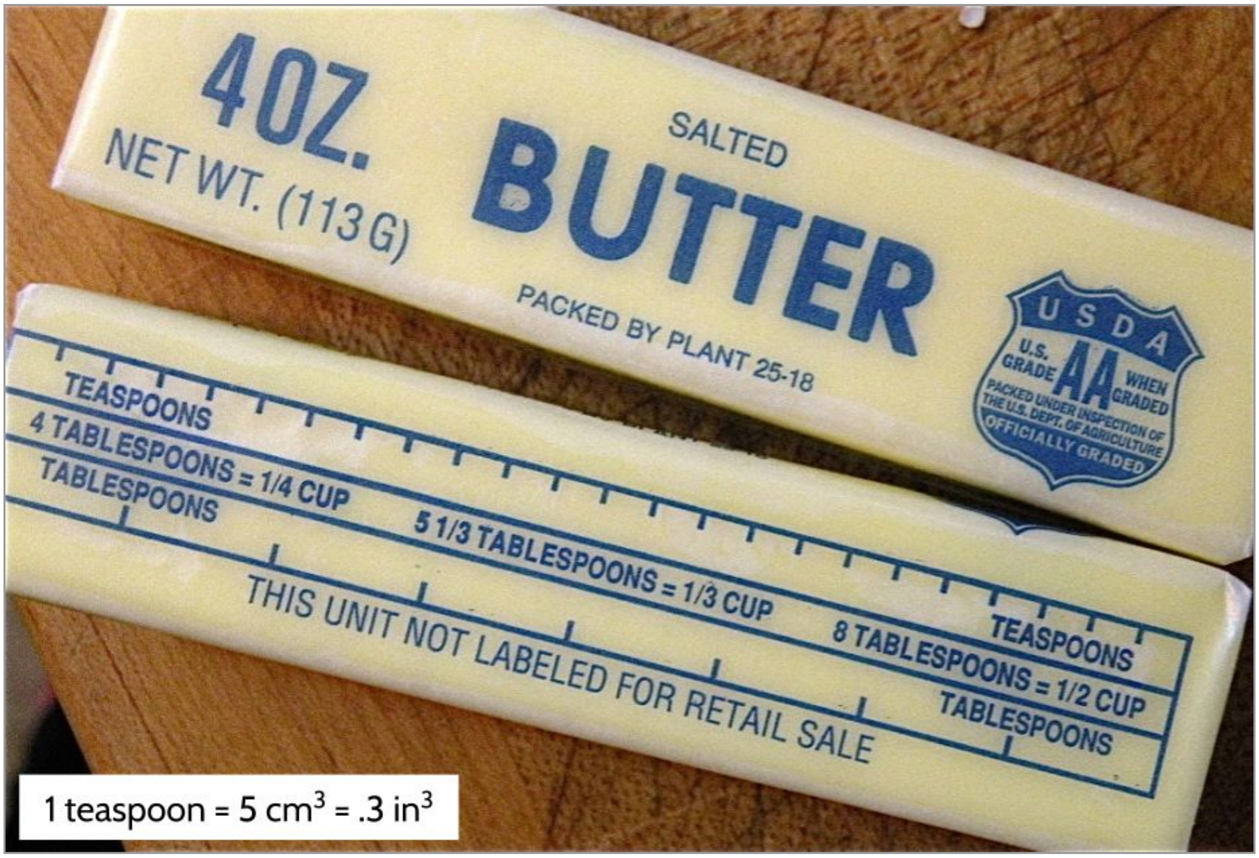
This movement of air around the room is called convection. Convection is one way that heat moves around in space. Warm air is less dense than cold air, so it rises off of the radiator. After the air rises to the ceiling and loses its heat, it becomes more dense and sinks. Warm air is less dense than cold air, so it rises. Cold air is denser than warm air, so it sinks. This is why attics are really hot in the summer and basements tend to be colder than the upper floors of a building.

Density of Air at Different Temperatures

Temperature (°F)	Density (g/cm^3)
100	.0011
70	.0012
40	.0013
10	.0014

As you see, the difference in density isn't very big, but it's enough to move air around a room. Actually, convection of air currents is also responsible for wind and weather systems. Cold air moving over a warm ocean can cause a hurricane!

Butter



25) Write as many statements as you can based on the information in the photo. Make sure each statement includes a number.

Density Practice

Fill in the missing information. Feel free to use a calculator. You can check your answers in Density of Common Materials - Answer Key.

	Material	Mass (g)	Volume (cm^3)	Density (g/cm^3)
26)	Air, atmospheric	1,225	1,000,000	0.001225
27)	Alcohol, methyl		500	0.792
28)	Butter	405		0.9
29)	Charcoal	9,000	45,000	
30)	Gasoline		2,000	0.72
31)	Gold	193.2		19.32
32)	Helium	0.5	3,000	
33)	Ice		500	.934
34)	Iron	3,026		7.86
35)	Olive oil	930	1,000	
36)	Steam (water vapor)		1,000,000	0.0006
37)	Steel	1,610		8.05
38)	Water (liquid)	1,000	1,000	

Circle the correct answer and then explain your answer.

39) Circle the material sample from the table with the larger mass.

A. Charcoal or gold

B. Gasoline or helium

40) Circle the material sample that has the biggest volume.

A. Butter or ice

B. Iron or steel

41) Circle the material with the lower density.

A. Atmospheric air or helium

B. Steam (water vapor) or water (liquid)

42) If you pour olive oil into a cup of water, will it sink to the bottom or float on top? Why?

43) Use density to explain why steam rises from a pot of boiling water.

Identify the Mystery Substance

Scientists use physical properties such as color, odor, texture and density to identify samples of different materials. Use the following chart of substances and their densities to identify the mystery substances below.

Substance	Density (g/cm^3)
Bronze	8.7
Charcoal	0.2
Coal	1.4
Gasoline	0.7
Gold	19.3
Methyl Alcohol	0.8
Oak	0.7
Pine	0.4
Salt	2.2
Sugar	0.9

Fill in the blanks in the table below.

	Physical Properties	Weight (g)	Volume (cm^3)	What is the mystery substance?
44)	rough, brown	80	200	
45)	metallic, golden	43.5	5	
46)	crystals, white	66	30	
47)	black, hard	2	10	
48)	clear, liquid	16	20	

Gold at a Discount

A man in a jewelry store tells you about a bargain. He is selling a golden cube for $500, saying that it is pure gold. He puts the cube on a scale and shows you that it weighs 90 grams. He then shows you on the Internet that the current price of gold is $40/gram. He says this is a great deal since 90 grams of gold would normally cost $3,600.

You measure the cube with a ruler and find that it measures 2 cm on each side. Then you look up the physical properties of gold for reference.

Gold
Symbol: Au
Atomic number: 79
Density: 19.3 g/cm^3

49) Should you buy the golden cube? Explain your answer.

Density of Common Substances - Answer Key

1) 150 pounds
2) 225 pounds
3) 25 pounds, 25 lb/ft^3
4) 50 pounds
5) 375 pounds
6) 37.5 pounds
7) In each function, *x* represents the volume of the pine as an input and *y* represents the weight as an output. Which formula correctly converts the volume into the weight?

Volume (x)	Mass (y)
3	75
5	125
8	200
10	250

Answer A is the correct choice. The function *y* = 25*x* means that every input for x is multiplied by 25 to get the output for *y*. 3 times 25 equals 75. 5 times 25 equals 125. 8 times 25 equals 200. Each measurement in volume is multiplied by the density of 25 lbs/cu. ft. to get the measurement in weight.

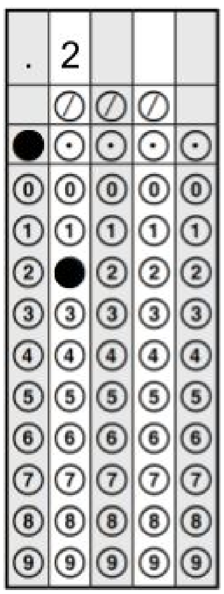
8) A, C, E, F
9) A - 12,500 pounds
   B - $3,750
10) Our guess is that the ice floated. Did it?
11) There are different things to notice.
    - 1 cm^3 of ice weighs .9 grams.
    - 2 cm^3 of ice weighs 1.8 grams.
    - 3 cm^3 of ice weighs 2.7 grams.
    - The dots make a straight line.
    - Each dot is .9 grams higher than the last one.
12) 0
13) 0.9
14) 1.8
15) 2.7
16) 3.6
17) 4.5
18) 9
19) 0.9 g/cm^3
20) We want to know what you think.
21) Ice should float because it has a lower density than water. A cubic centimeter of ice is lighter than a cubic centimeter of water.

22) There are a couple ways to think about this. When frozen water gets bigger, the mass spreads out across more space, so it's less dense. There is less weight for each cubic centimeter of volume. You could also think about the density formula:

$$\frac{mass}{volume} = density$$

To get density, we divide mass by volume. If the volume number gets bigger and the mass number stays the same, then the density number gets smaller.

23)



24) The warm air is rising up to the ceiling, then moving across the ceiling. When the air cools, it sinks back to the floor and moves back towards the radiator.

25) There are many possible statements. Here are some:

- There are 8 tablespoons in ½ cup.
- There are 3 teaspoons in 1 tablespoon.
- There are 12 tablespoons in ¼ cup.
- There are 24 teaspoons in ½ cup.
- There are 16 tablespoons in 1 cup.
- 6 teaspoons of butter weighs 1 oz.
- There are 15 cm^3 in a tablespoon.
- There are 120 cm^3 in a stick of butter.
- There are .9 in^3 in a tablespoon.
- There are 7.2 in^3 in a stick of butter.
- The density of butter is .94 g/cm^3
- The density of butter is .56 oz/in^3

26) .001225 g/cm^3

27) 396 g

28) 450 cm^3

29) 0.2

30) 1,440

31) 10

32) 0.0001666...

33) 467

34) 385

35) .93

36) 600

37) 200

38) 1

39) A - The charcoal (9,000 g) is heavier than the gold (10 g).
B - The gasoline (1,440 g) is heavier than the helium (.5 g).

40) A - The ice (500 cm^3) has a bigger volume than the butter (450).
B - The iron (385 cm^3) has a bigger volume than the steel (200 cm^3).

41) A - Helium (0.000167 g/cm^3) has a lower density than atmospheric air (0.001225 g/cm^3).
How do we know 0.000167 is smaller than 0.001225? The 1 in 0.001225 is in the thousandths place, which mean that air weighs a bit more than $\frac{1}{1000}$ gram per cubic centimeter. The 1 in 0.000167 is in the ten thousandths place, which means that helium weighs a little more than $\frac{1}{10000}$ gram per cubic centimeter. One ten thousandth ($\frac{1}{10000}$) is much smaller than one thousandth ($\frac{1}{1000}$).
B - Steam (0.0006 g/cm^3) has a lower density than liquid water (1 g/cm^3).

42) The oil will float on top of the water because it was a lighter density than water (0.93 g/cm^3 compared with 1 g/cm^3).

43) Steam (0.0006 g/cm^3) has a lower density than air (0.001225 g/cm^3), which makes it lighter than air, so the steam rises off of the boiling water.

44) pine

45) bronze

46) salt

47) charcoal

48) methyl alcohol

49) No. The “golden” cube has a volume of 8 cubic centimeters. With a mass of 90 grams, its density is 11.25 g/cm^3, much less than pure gold. If the cube was made of gold, it would weigh 154.5 grams, so it’s too light. Something is wrong. Maybe it’s gold-plated or mixed with another metal.

Test Practice Questions

Answer the following questions. Feel free to use a calculator. You can check your answers in Test Practice Questions - Answer Key.

1) The following chart shows the mass (grams) and volume (milliliters) of four liquid samples.

Liquid	Mass (g)	Volume (ml)
Honey	504	355
Rubbing Alcohol	395	500
Vegetable Oil	870	946
Water	237	237

Part I: Based on the chart, which liquid has the highest density?

A. Honey

B. Rubbing Alcohol

C. Vegetable Oil

D. Water

Explain your answer:

Part II: If these four liquids were combined in a jar, which liquid would rise to the top?

A. Honey

B. Rubbing Alcohol

C. Vegetable Oil

D. Water

Explain your answer:

2) A cube of platinum weighs 73.1 grams and has a volume of 3.4 cubic centimeters. What is the approximate density of the platinum?

   A. 0.047 grams per cubic centimeter

   B. 21.5 grams per cubic centimeter

   C. 69.7 grams per cubic centimeter

   D. 248.5 grams per cubic centimeter

Explain your answer:

3) The density of an object is

   A. The volume divided by the mass (*D = v/m)*

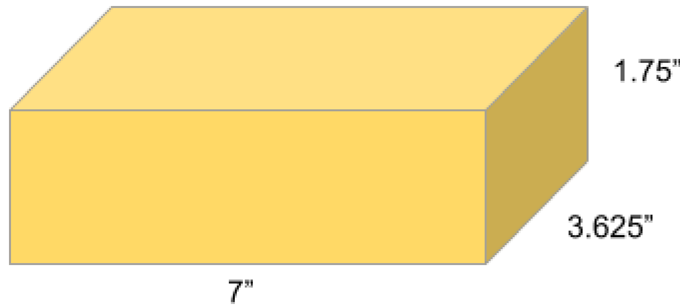
   B. The mass divided by the volume (*D = m/v)*

   C. The same as its weight

   D. The same as the size of the object

Explain your answer:

4) In the American system of measurement, the density of gold is about .7 pounds per cubic inch. The dimensions of a standard gold bar are 7 inches by 3.625 inches by 1.75 inches. About how heavy is a solid gold bar?



A. 5 lb

B. 9 lb

C. 31 lb

D. 63 lb

Explain your answer:

5) The density of salt is 2.16 grams per cubic centimeter. A restaurant manager ordered a delivery of bags of salt, each of which weighs 500 grams. What is the volume of one of these bags of salt?

A. 231 cm^3

B. 498 cm^3

C. 502 cm^3

D. 1080 cm^3

Explain your answer:

6) The density of honey is 1.45 grams per milliliter. If the honey in a full jar weighs 250 grams, what is the volume of the jar?

   A. 172 ml

   B. 251 ml

   C. 363 ml

   D. 395 ml

Explain your answer:

7) The density of brass is .3 pounds per cubic inch. One pound is approximately 453.6 grams. One cubic inch is approximately 16.4 cubic centimeters. What is the approximate density of brass in grams per cubic centimeter?

   A. 4.9 g/cm^3

   B. 8.3 g/cm^3

   C. 27.7 g/cm^3

   D. 136.1 g/cm^3

Explain your answer:

8) A wooden cube has an edge length of 6 centimeters and a mass of 137.8 grams. Determine the density of the cube, to the nearest thousandth. Then use the table below to identify the wood.

Type of Wood	Density (g/cm^3)
Pine	0.373
Hemlock	0.431
Elm	0.554
Birch	0.601
Ash	0.638
Maple	0.676
Oak	0.711

State which type of wood the cube is made of, using the density table above.

A. Ash

B. Elm

C. Oak

D. Pine

Explain your answer:

Test Practice Questions - Answer Key

1) Part I: The correct answer is **A** (*Honey*). Honey is also the only substance where the mass is greater than the volume, so all the other substances have densities of less than 1. Honey's density of 1.42 g/ml can be calculated by dividing the mass (504 g) by the volume (355 ml). This is higher than the calculated density of each of the other liquids: rubbing alcohol (.79 g/ml), vegetable oil (.92 g/ml), water (1 g/ml).

   Part II: The correct answer is **B** (*Rubbing Alcohol*). Its density of .79 g/ml is lower than the density of the other liquids. Since rubbing alcohol is lighter that the other liquids, it will float to the top of the jar.

   Here's a challenge question: Can you predict the order of all four liquids as they separate in a jar?

2) B - 21.5 grams per cubic centimeter

3) B - The mass divided by the volume (*D = m/v)*

4) C - 31 lb

5) A - 231 cm^3

6) A - 172 ml

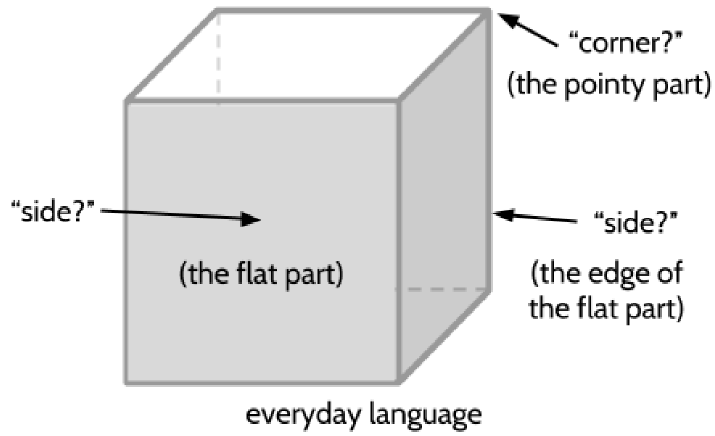
7) B - 8.3 g/cm^3

8) A - Ash

The Language of Density

Parts of a Cube

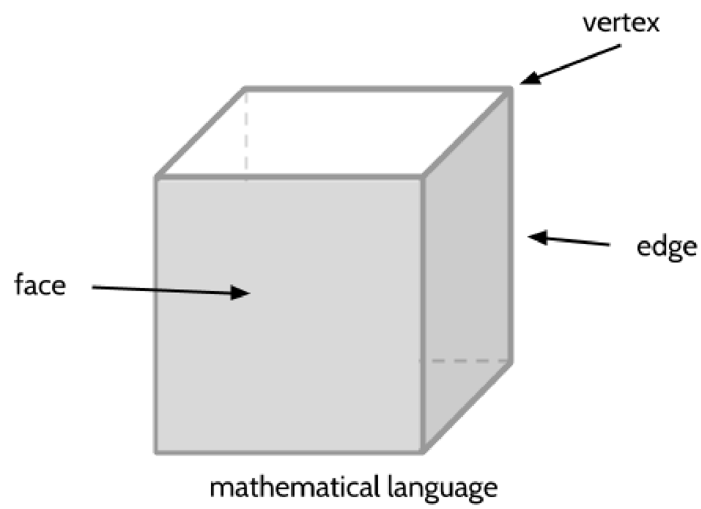
In everyday language, we might talk about the "sides" of a cube, but this can be confusing. If you hear someone say "sides," you might wonder if they mean the flat part of dice where the dots are or if they mean the edge of the flat part where it turns a corner. Using everyday English to describe cubes can be ambiguous, or unclear.



Because the everyday language we use to describe cubes can be confusing, mathematicians have developed specific words for these parts of a 3-dimensional shape.

The flat part is called a *face*. Like we saw earlier with dice, cubes have 6 faces. The *edge* is where different faces of the shape meet. This is the line along the side of the cube. Finally, the corner point is called a *vertex*. The vertex is where the different edges of the shape meet.

The words face, edge and vertex are used for all kinds of 3-dimensional shapes.



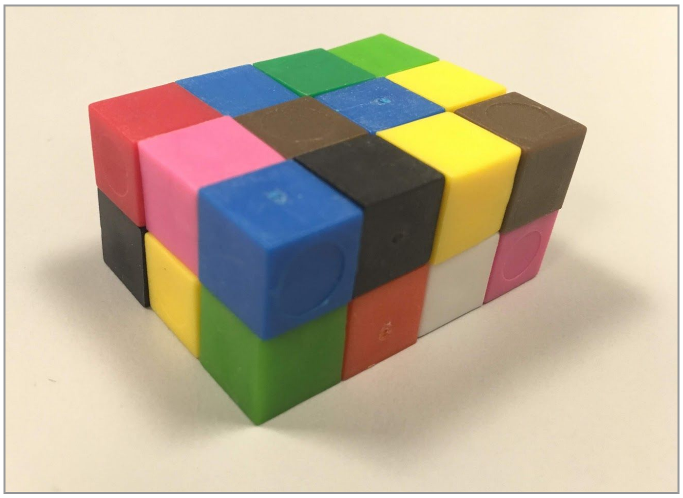
1) How many vertices does a cube have? __________

2) How many faces does a cube have? __________

3) How many edges does a cube have? __________

How Math is Written

In learning mathematics, knowing how to write your answer is important so that other people understand what you mean. Mathematics notation is the way in which mathematicians write to communication with other mathematicians. Learning this kind of notation is like learning a new language, but it's helpful so that you understand other people and they will understand you.



As you know, volume is the amount of 3-dimensional space an object takes up, measured in cubic units. When you write an volume measurement, you can use any of the following ways of writing the volume of the stack of cubes above:

24 cubic centimeters   24 cm^3 24 cu. cm.   24 cc

When you see a measurement like **24 cm^3**, this is what it means:

24 cm^3

3 ← The 3 means that you're measuring volume and that cubes used to fill the space. It means that the centimeters are "cubic." It **doesn't** mean "to the third power."

cm ← "cm" is short for "centimeters." Each cube measures 1 centimeter on each side.

24 ← 24 cubes fill the space without gaps or overlapping.

4) Fill in the missing boxes in this table.

10 cubic cm →	10 cu. cm.	10 cm^3
7 cubic inches→		
→		12 cm^3
→	8.5 cu. in.	
1/2 cubic meter →		
36 cubic feet →		
→		12 mi^3

5) Which of these are other ways to write one cubic inch?

A. 1 in

B. 1 in^2

C. 1 in^3

D. 1 cu. in.

6) Which of these are other ways to write one cubic centimeter?

A. 1 cm

B. 1 cm^2

C. 1 cm^3

D. 1 cu. cm.

E. 1 cc

Using Graphic Organizers to Learn Vocabulary

In order to learn math vocabulary, we need practice using it in different ways. In this activity, you will choose a few words from this packet that you want to practice, then you will complete a graphic organizer for each word. Look at the sample for the word *quotient* below.

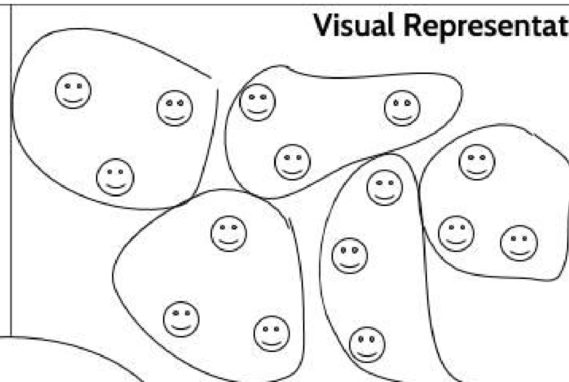
To complete the graphic organizer, you will choose a word and then answer four questions:

- What is the definition of the word? You can look at the vocabulary review on page 86 for help. Try to write the definition in your own words to really make the word yours.
- Make a visual representation. You can make a drawing or diagram that will help you remember what the word means.
- What are some examples of the word you're studying? Below you can see that there are examples of *quotients*, which are the answers to division problems.
- What are some non-examples of this word? These are things that are **not** the word you're studying. For example, 24 is **not** the quotient of 4 divided by 6.

What is it?

A quotient is the result of dividing one number by another. It is the answer to a division question.

Visual Representation



quotient

What are some examples?

15 divided by 3 equals **5**

66 ÷ 6 = **11**

63/18 = **3.5**

5, 11 and 3.5 are quotients in these calculations.

population ÷ area = **density**

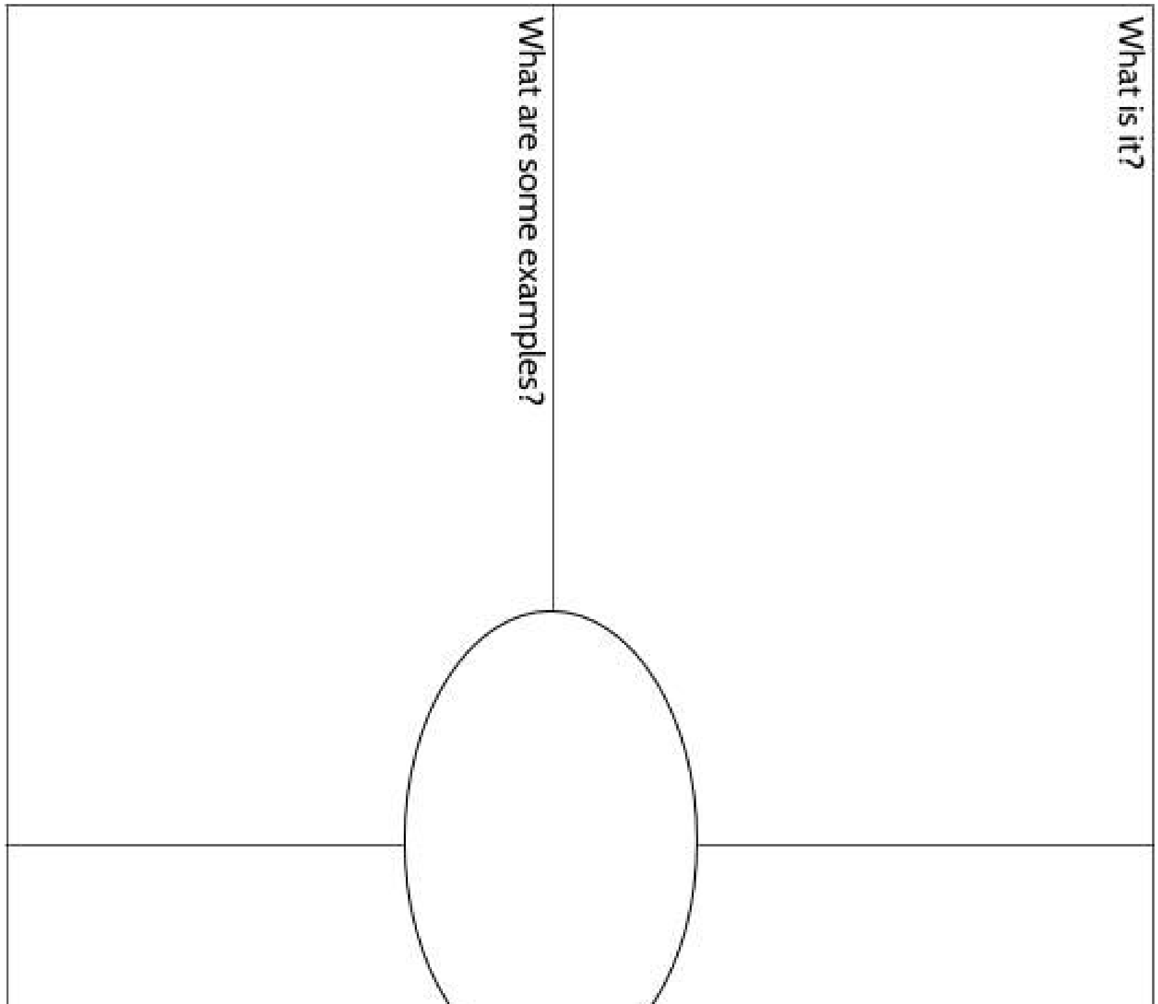
What are some non-examples?

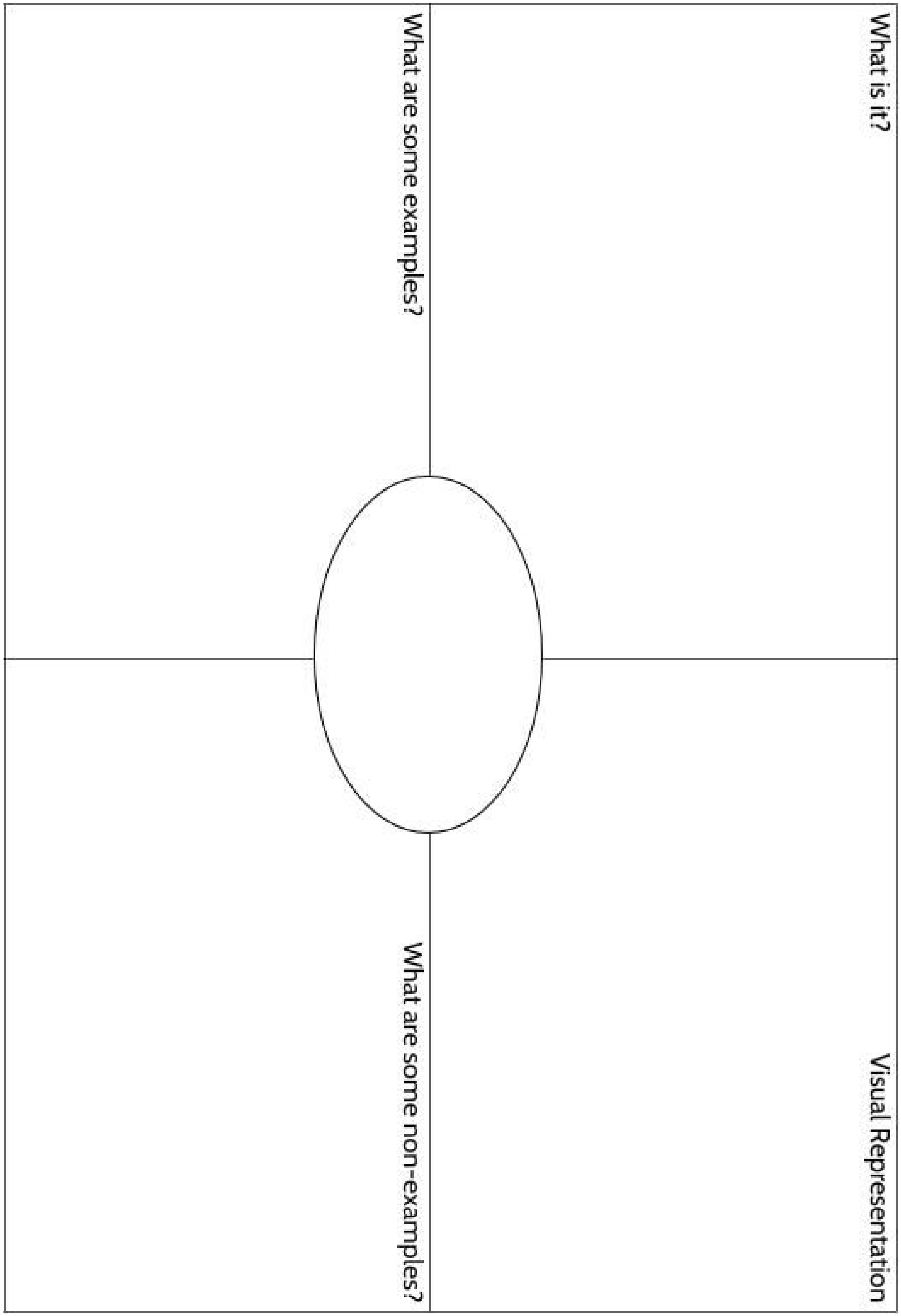
4 times 6 equals 24

18 + 5 = 23

17 – 2.5 = 14.5

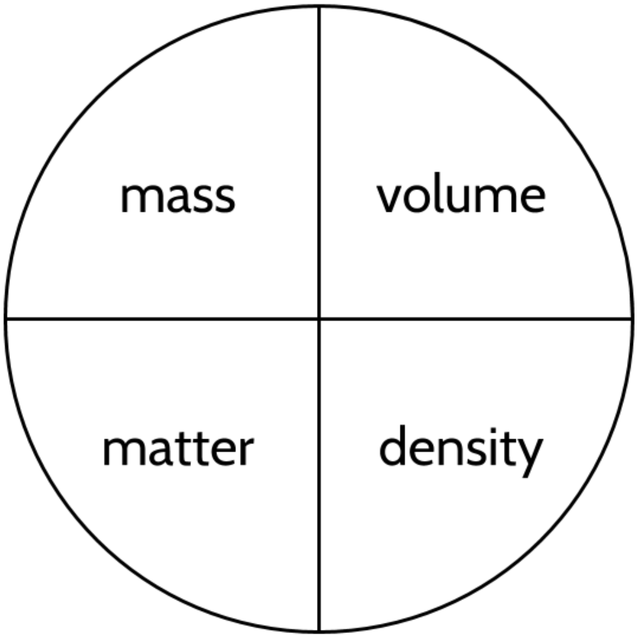
3.5 × 18 = 63

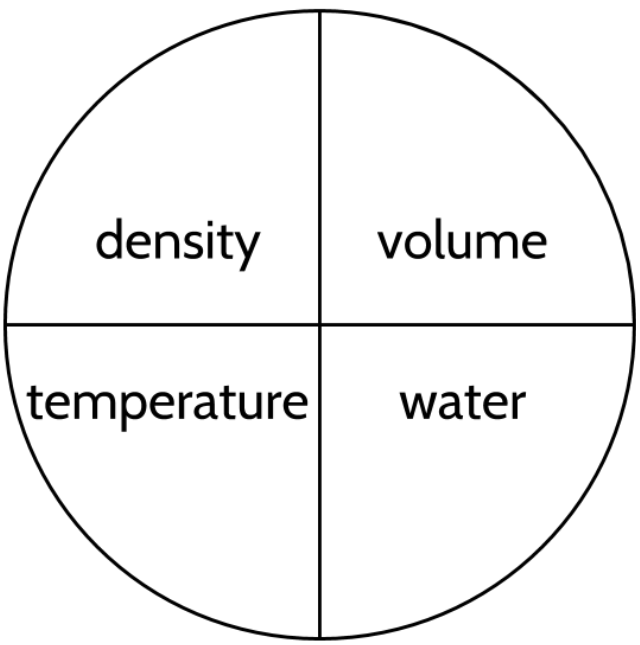

What is it?
What are some examples?
What are some non-examples?
Visual Representation


What is it?
What are some examples?
Visual Representation
What are some non-examples?

Concept Circle

7) Explain these words and the connections you see between them.





Fill in the Blanks

8) Use the words and measurements below to fill in the blanks in the article.

physical property   high   air   compare   warms up   low   1.27 g/cm^3 sink   temperature   mass   goes down   paperclip   increases   compact   freezes   length, width and height   less dense   cubic units   float   2.7 grams   5 quarters   ounces and pounds   convection   grams and kilograms   ~~density~~   volume   light and sound   cannot   measurement   high   1 g/cm^3

The density of matter is an important topic in science and math. Matter is anything that has ____________________ and ____________________ . Almost everything we see around us is made of matter, though ____________________ are examples of things that are not made of matter.

The mass of an object is a measure of how much matter is in the object. Mass can be measured with a scale. ____________________ are common measures of mass in the American system. As a way to remember, an ounce is the weight of ____________________ . ____________________ are measures of mass in the metric system. A gram is the weight of a ____________________ . For practical purposes, mass means the weight of an object. The volume of an object is how much space it takes up. We measure volume by counting how many ____________________ fit in a space. If an object is in the form of a rectangular prism (box), its volume can be calculated by multiplying the

____ .

Anything made of matter has density. Density is a ____________________ that describes how heavy a substance is for its size. It compares the mass of an object to its volume. An object, such as a golf ball, with a lot of mass in a small volume has a _________________ density. The matter inside substances with high density is ____________________ or packed together tightly. An object, such as a ping pong ball, with a small amount of mass in the same amount of volume has a ____________________ density.

Density is calculated by dividing the mass of an object by its volume.

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

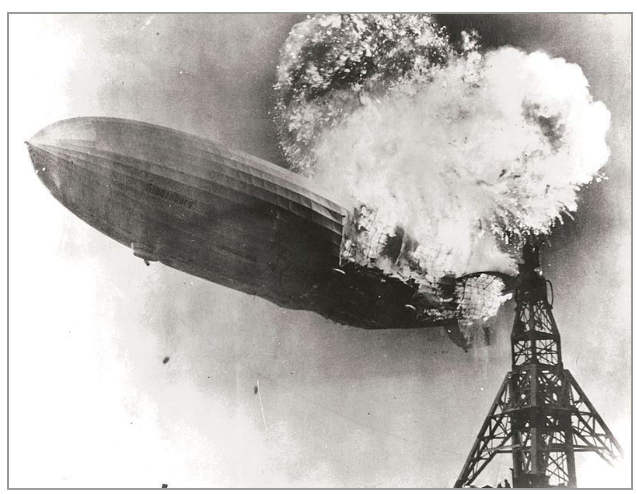
where d is the density, m is the mass, and v is the volume.

With a mass of 46 grams and a volume of 40.8 cm^3, a golf ball has a density of about ____________________ . With a mass of ____________________ and a volume of 33.5 cm^3, a ping pong ball has a density of about .08 g/cm^3.

We can also think of a density measurement as a physical property. Substances such as water, silver, gold, oxygen, and carbon all have a certain density, the same way they all are a certain color. Physical properties can be used to identify substances. For example, copper is a shiny, reddish-brown metal and has a density of 8.96 g/cm^3. These two physical characteristics describe copper wherever it is found. Each substance has a specific density, so if you find a shiny, reddish-brown metal with a density of 8.96 g/cm^3, it is probably copper. Color is a ______________________ that can be seen, but density ______________________ be directly seen by looking at an object. It must be calculated from the relationship between the mass and volume.

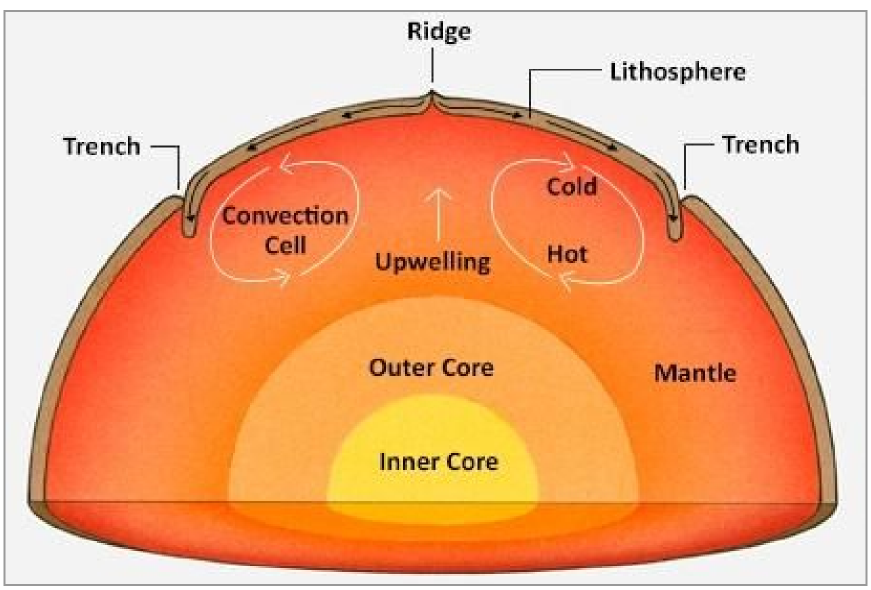
The density of water is often used to ______________________ the densities of other substances. If an object has a density that is lower than water's density of ______________________ , it will ______________________ in water. If a object's density is higher, the material will ______________________ in water.

Increasing the ______________________ of a substance usually increases its volume. For example, you can open a tight lid on a jar with hot water because metal expands when it gets hot. Air grows in volume as it warms up. Doors to houses sometimes stick in hot weather. When a substance grows in volume, but keeps the same mass, the density ______________________ . However, there are exceptions. When ice melts (gets warmer), it shrinks in volume. When water ______________________ , it expands by about 9% in volume, making ice that is less dense than liquid water.



Density can be used to explain the behaviour of materials in the world around us. For example, ice floats in water because it is ___________________ than water. In a bottle of salad dressing, oil rises above vinegar because vinegar has a higher density than oil. Balloons filled with helium float in the air because the density of helium is lower than the density of atmospheric air. Hot air balloons are able to carry people through the air because hot air is less dense than cool air and pulls the balloon into the sky. Hydrogen also has a lower density than ____________________ and was once used in blimps, similar to hot air balloons, though it is used less after the famous disaster in 1939 when the Hindenburg airship crashed and burned.

Density even explains the weather. As air warms up, its volume ____________________ . Since its mass stays the same, it becomes less dense and rises above cooler air. The cycle of air caused by rising warm air and falling cold air is called ____________________ . When cold air flows over warm ocean water in the Caribbean, it ____________________ , picks up moisture and rises, producing clouds and wind. As the air cools, it loses moisture as rain and falls back to Earth. The cycle of warm and cold air creates wind. Convection happens whenever fluids (including water and air) are heated up. For example, the circulation of warm and cold fluids also happens in a room with a radiator, a boiling pot of water on the stove, and with melted rock on the inside of the Earth.



Density in Your Life

9) Look around you. Where do you see density? Describe the world you see using as many of the density vocabulary words on page 87 as you can.

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The Language of Density - Answer Key

1) 8

2) 6

3) 12

4) 10 cubic centimeters, 10 cu. cm., 10 cm^3
7 cubic inches, 7 cu. in., 7 in^3
12 cubic centimeters, 12 cu. cm., 12 cm^3
8.5 cubic inches, 8.5 cu. in., 8.5 in^3
1/2 cubic meters, 1/2 cu. m., 1/2 m^3
36 cubic feet, 36 cu. ft., 36 ft^3
12 cubic miles ,12 cu. mi., 12 mi^3

5) C, D. You can use *in^3* or *cu. in*. to abbreviate cubic inches. The exponent ^{3} refers to a cube's three dimensions: Length, height and width.

6) C, D, E. You can use *cm^3*, *cu. cm*., or cc to abbreviate cubic centimeters. The exponent ^{3} refers to a cube's three dimensions: Length, height and width.

7) Each paragraph should use the 4 vocabulary words in the circle on the left. Be creative. There is no right way to do this activity!

8) mass
volume
light and sound
Ounces and pounds
5 quarters
Grams and kilograms
paperclip
cubic units
length, width and height
measurement
high
compact
low
1.27 g/cm^3
2.7 grams
physical property
cannot
compare
1 g/cm^3
float
sink
temperature
goes down
freezes
less dense
air
increases
convection
warms up

9) Take your time with this activity. Look around you and look for evidence of density. You might even do some research so that you have some numbers to include in your writing. This is an opportunity to practice all the vocabulary and math skills you have learned.

Vocabulary Review

You can use this section to look up words used in this math packet.

area (noun): The size of a flat surface, measured in square units

atom (noun): A very small bit of matter which makes up a chemical element

compact (adjective): Closely packed together; dense

- Iron is a more *compact* substance than styrofoam.

convection (noun): The movement within a fluid caused by the rising of hotter, less dense materials and the sinking of colder, denser material

- *Convection* causes movement of air around a room.

convert (verb): The change from one thing into another

- You can *convert* kilograms into pounds by multiplying by 2.2.

cube (noun): A box-shaped solid object that has six identical square faces.

dense (adjective): Crowded closely together or packed together

- Water is more dense than ice.
- Helium is less dense than air.

density (noun): A measure of how compact or "pushed together" things are in a space

The word dense comes from the Greek word *dasus*, which means "compact."

density in science: The amount of mass per unit of volume

population density: The average number of people or things per square unit of area (This topic is covered in a separate student packet.)

edge (noun): A line segment between faces.

- Cubes have twelve *edges*.

element (noun): Each of more than one hundred substances that make up matter, are made of one particular atom and cannot be broken down into simpler substances

estimate (verb): to make a rough guess at a number, usually without making written calculations

face (noun): A flat surface on an object such as a cube or a rectangular prism.

- Cubes have six *faces*.

line segment (noun): Part of a line that connects two points.

per (preposition): For each or for every

- Gold weighs 19.3 grams *per* cubic centimeter.

rectangle (noun): A 4-sided flat shape with straight sides which has:

  - Four sides
  - Opposite sides of equal length
  - Four right angles (90°)

rectangular prism (noun): A solid (3-dimensional) object which has six faces that are rectangles.

square (noun): a 4-sided, flat shape which has:

  - Four straight and equal sides
  - Four right angles (90°)

substance (noun): A particular kind of matter

Synonyms: material, stuff

unit (noun)**:** a quantity of one used to measure other quantities

- Inches, feet, centimeters and meters are all *units* for measuring distance or length.
- Square inches, square feet, square centimeters, and square meters are all *units* for measuring area.
- Cubic inches, cubic feet, cubic centimeters, and cubic meters are all *units* for measuring volume.

vertex (noun): A point where two or more line segments meet.

- A cube has eight vertices (plural of *vertex*).

volume (noun): a measurement of the 3-dimensional space something takes up