Supplementary Material

[Following is the translated questionnaire for students who are sighted. The questionnaire was given to students in four different versions with different question order]

Student nr. _____

Date _____

Hello,

We want to thank you in advance for participating in this research about learning through modeling.

Your participation is on a voluntary basis and your grade will not be effected even if you choose not to participate in the research.

The purpose of this questionnaire is to allow us to check you learning in the unit.

Your identity will be kept strictly confidential. The questions do not have right or wrong answers.

Important: Please answer the questions <u>in the order</u> they are presented and don't go back.

The questionnaire should take no longer than 35 minutes to complete.

Thank you for your help,

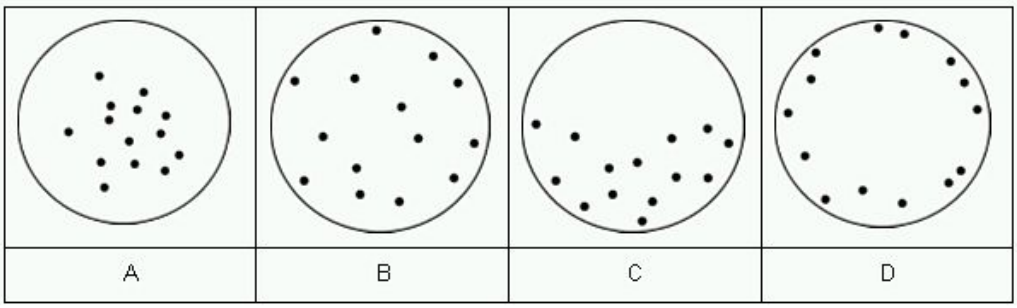
The researchers

Please read the text below and answer questions 1&2.

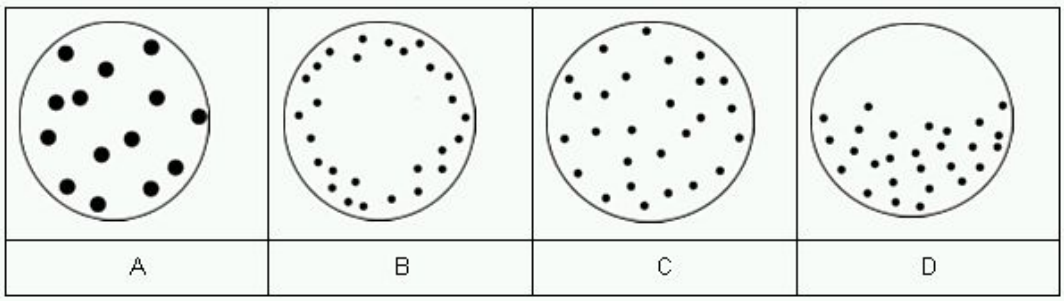
A group of players wanted to play basketball. They brought a basketball that looked just fine. But when they tried to bounce the ball, it did not bounce well. After they pumped up the ball with air, it bounced very well.

Suppose we could look at the air through magnification that is strong enough so that we could see the particles of air. In the following images the particles are represented by dots. The dots are much bigger than the actual size of the real particles. The size of the ball that represents the basketball is equal in all four images.

1. Which image best describes the scattering of the air particles in the basketball **before** it was inflated?

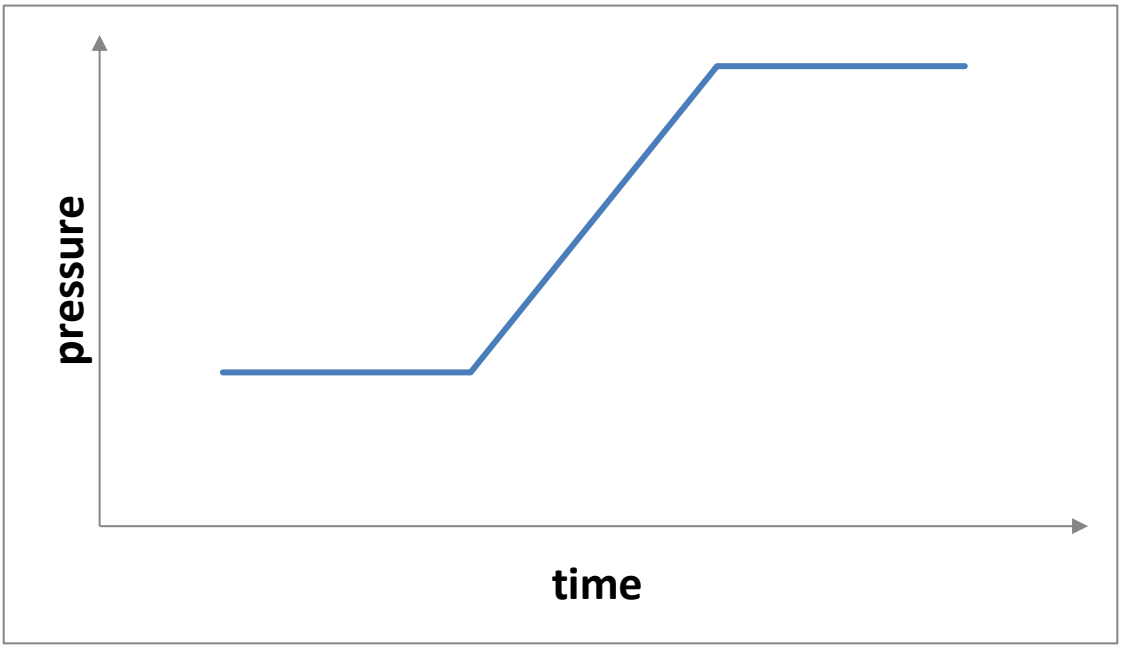


2. Which image best describes the scattering of the air particles in the basketball **after** air was added to it?



Questions 3 to 5 refer to the graph below. Look at the graph and answer the questions.

The following graph shows how the air pressure inside the basketball changes with time.



3. Please describe how the pressure inside the basketball changes with time.

a. The pressure increases constantly.

b. At first the pressure is constant and then it decreases and remains stable.

c. The pressure increases for a short time and then remains constant.

d. At first the pressure is constant, then the pressure increases gradually, and finally the pressure remains constant.

4. Which of the following conditions could have caused the pressure to change in this way?

a. Someone stepped on the basketball, squeezed it, and made it look smaller.

b. The basketball was cooled by placing it in a freezer.

c. The basketball had a leak (a hole which let air out).

d. None of the conditions above are correct.

5. What changes occur in the air particles in this situation?

a. The particles get bigger and take up more space.

b. The particles become faster and collide with the basketball's wall more frequently.

c. The particles collide with each other and with the basketball's wall more frequently.

d. All the answers are correct.

Questions 6 and 7 refer to the text below; please read it and answer the questions:

A basketball is pumped up with air. Let's assume that the size of the basketball doesn't change and that the temperature is constant.

6. What happened to the frequency with which air particles collided with the basketball's wall after it was pumped up?

a. Increased

b. Decreased

c. Did not change

7. What happened to the air particles as the basketball was pumped up?

a. The air particles collided with the basketball's wall more frequently and collided with each other less often.

b. Air particles collided with the basketball's wall more frequently and collided with each other more often.

c. The air particles collided with the basketball's wall less frequently and also collided with each other less frequently.

d. The air particles collided with the basketball's wall less frequently but collided with each other more frequently.

8. The Kinetic Molecular Theory describes how gas particles behave under ideal conditions. Which of the following sentences does not describe the behavior of air particles according to the Kinetic Molecular Theory?

a. Gas particles move in straight lines until they collide with something.

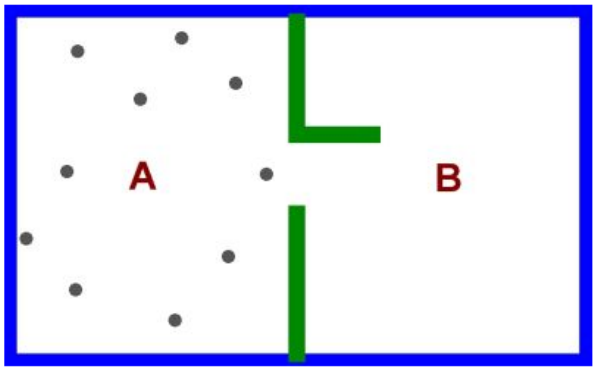
b. When gas particles hit a wall, they bounce back, with no change in speed.

c. Gas particles are much smaller than the distance between them.

d. When two gas particles collide they may react and behave as a new substance.

Questions 9 to 12 refer to the text and image below; please read the text, explore the image, and answer the questions.

Try to imagine a box with a partitioning wall inside it as in the following image. The left side of the box (A) contains a gas. A window is then opened in the wall that separates the two parts of the container.



9. Which statement best describes the gas particles' motion?

a. The gas particles move about randomly. If they happen to reach the window they go through to area B. Particles from area B can return to area A.

b. The gas particles move about randomly. If they happen to reach the window they go through to area B. Particles from area B cannot return to area A.

c. The gas particles in area A move about randomly. When the window opens, they head for the window with the intention of filling the empty space in area B. Particles that moved to area B can return to side A.

d. The gas particles in area A move about randomly. When the window opens, they head for the window with the intention of filling the empty space in area B. Particles that moved to area B cannot return to side A.

10. How would you describe the motion of a single particle?

a. The particle tends to move more to the right than to the left.

b. The particle moves in a random motion depending on the direction of the gas movement and what objects it collides with.

c. The fastest particles are quick to move toward the empty space that opened up.

d. When the empty space is opened, a vacuum is created that sucks the particles into it.

11. When a particle collides with the wall of the box:

a. The particle changes direction but its speed remains constant.

b. The particle changes direction and speed.

c. The particle changes speed but its direction does not change.

d. The particle does not change direction nor speed.

12. When two gas particles collide:

a. The particles change directions but their speeds remains constant.

b. The particles change both speed and direction.

c. The particles change speed but their direction remains constant.

d. The particles don't change speed nor direction.

13. How does the mass of the particle effect its speed in conditions of constant pressure and temperature?

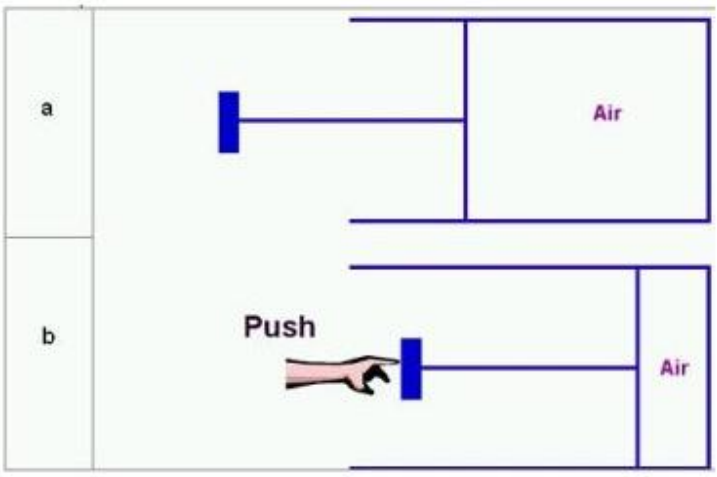
a. The larger the mass of the particles, the faster their movement.

b. The smaller the mass of particles, the slower their movement.

c. There is no connection between the mass of particle mass and their speed.

d. The larger the mass of the particles, the slower their movement.

Questions 14 – 17 refer to the image below:



The image shows a sealed syringe with the piston in two states, A and B. In state B, the piston has been pushed in without changing the amount of air in the piston. Let us assume that there was no change in energy or temperature.

14. The volume of air is:

a. Greater in A.

b. The same in the two states A and B.

c. Greater in B.

15. The density of the particles of air is:

a. Greater in A.

b. The same in the two states A and B.

c. Greater in B.

16. The average speed of the particles is:

a. Greater in A.

b. The same in the two states A and B.

c. Greater in B.

17. The frequency of particle collisions is:

a. Greater in A.

b. The same in the two states A and B.

c. Greater in B.

18. If a gas inside a container is cooled, what would you expect to happen to the gas pressure?

a. The pressure will decrease.

b. The pressure will not change.

c. The pressure will increase.

d. It is impossible to know what will happen.

19. Suppose you increase the number of gas particles in a container. The volume of the container stays constant. How will the addition of particles affect pressure?

a. The pressure will decrease.

b. The pressure will not change.

c. The pressure will increase.

d. It is impossible to know what will happen.

20. A girl sprays some perfume on her neck. Her mother, who was standing on the other side of the room, called out: "What a lovely smell".

a. Mark in the image below how the perfume particles from the girl's neck (lower left corner) reached her mother's nose on the other side of the room (upper right corner). Draw inside the rectangular box. Use small circles to depict the particles.

b. Please explain your illustration. Describe in words how the perfume particles made their way from one side of the room to the other side. Explain all the details involved in this process.

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21. The pressure in a bicycle tire changes throughout the year, even if there is no leak and even if no air is added to the tire. The change is caused by outside temperature changes that cause a temperature and pressure change inside the tire. What will happen to the pressure in the tire when the seasons change from summer to autumn to winter?

a. The pressure will increase.

b. The pressure will remain constant.

c. The pressure will decrease.

d. It is impossible to know what will happen.

22.1 During diffusion particles usually move:

a. From high concentration to low concentration of the substance.

b. From low concentration to high concentration of the substance.

22.2 What is the reason for your answer?

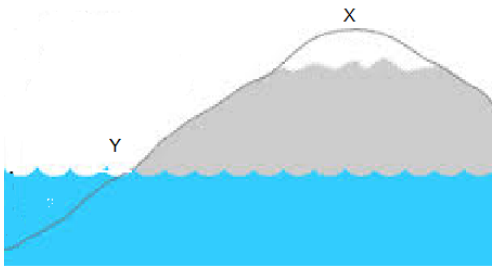
a. There are too many particles clustered in one area, so the particles move to an area with more space.

b. All particles move randomly, collide with other particles, and move in different directions. This movement causes an equal dispersion of particles in all areas.

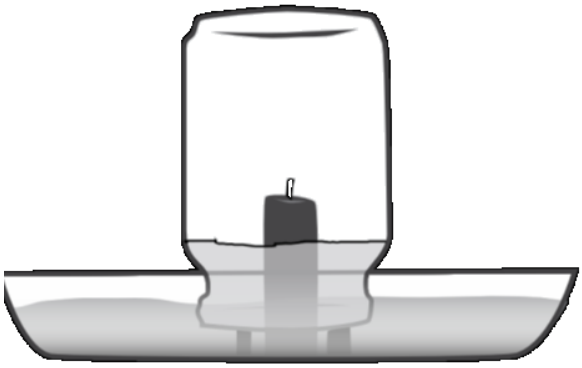
c. The particles tend to move until they are distributed equally in all areas; when they are equally dispersed in all areas, they stop moving.

d. Particles have a tendency to disperse themselves.

24. The air pressure at the top of Mount Everest (point X) is one-third of the air pressure near the seashore (point Y).



Please try to explain this phenomenon.



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2

24. Following is an experiment where a lit candle is placed in a saucer filled with water. The candle is covered with a glass jar as can be seen in figure 1. After a while the water starts to rise in the glass and the candle goes out as can be seen in figure 2.

a. Please mark the particles of air in figures 1 and 2.

b. Please try to describe in as much detail as you can why the water rises in the upside-down jar.

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Thank you for your cooperation.