centre de
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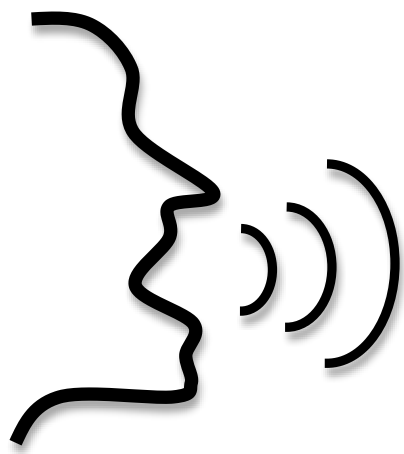
Working document

Theoretical capsule about the propagation of a sound (Intended for personnel)

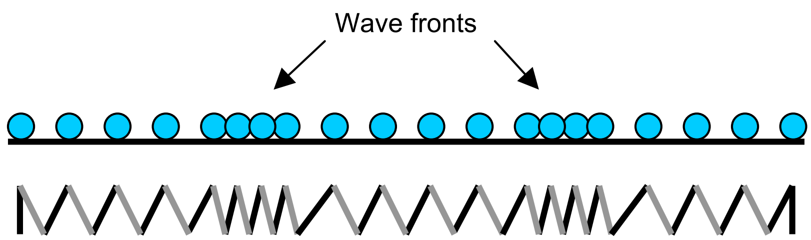


November 2014

To begin this capsule, let's specify that the expression "sound wave" is the scientific name for sound. This type of wave is in fact a distortion of the environment, which starts from one point and transports a certain amount of energy.

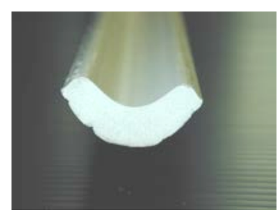
Analogies are often used to explain what a wave really is. The most popular is without a doubt the analogy between sound waves and waves at the surface of the water. This way of visualising sound waves is not without interest. Indeed, when a source emits a sound, this sound is propagated in space, a little like the circular waves created when an object is dropped into water. Another interesting analogy between the two phenomena is the fact that matter is not displaced with the wave. In the case of the wave, water particles rise and fall without moving horizontally. In the case of sound, the particles of matter oscillate slightly around a certain position and generally don't move with the wave that is propagated either.

The analogy with waves at the surface of water is limited, however, because the sound wave in the air is, in fact, a compression wave. The gas that supports the sound wave does not rise and fall, as is the case in waves in water. The particles of matter get closer and further to each other with the changes in pressure. An interesting analogy to visualise this phenomenon is the propagation of waves in a compressed spring. In this drawing, the zones where the spring is compressed represent the areas where, in the air, the particles are very close to one another. These are called "waves fronts".



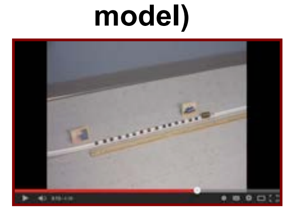
Now we will simulate the particles of matter by representing them with marbles. These demonstrations will allow the phenomenon of sound propagation in matter (in air, for instance) to be better understood.

Some demonstrations



Concretely, several glass marbles are aligned in the groove of a moulding, which becomes a ramp guiding the marbles. This assembly simulates the propagation of a sound wave front in air, in a single direction.

Videos of these demonstrations available on YouTube (Marble model)

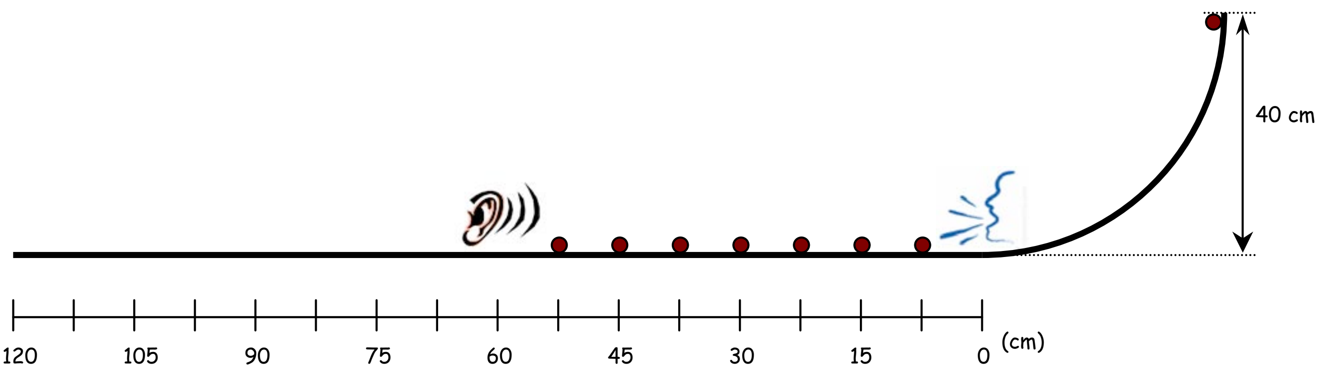


Here are the 5 themes broached:

1. The propagation of a sound wave between two points
2. The absorption of a sound wave
3. The energy transported by a sound wave
4. The reflection of a sound wave (the formation of an echo)
5. The speed of a sound wave.

YouTube: https://www.youtube.com/watch?v=Pf6GBr6Kik8

Demonstration 1 (The propagation of a sound wave between two points)



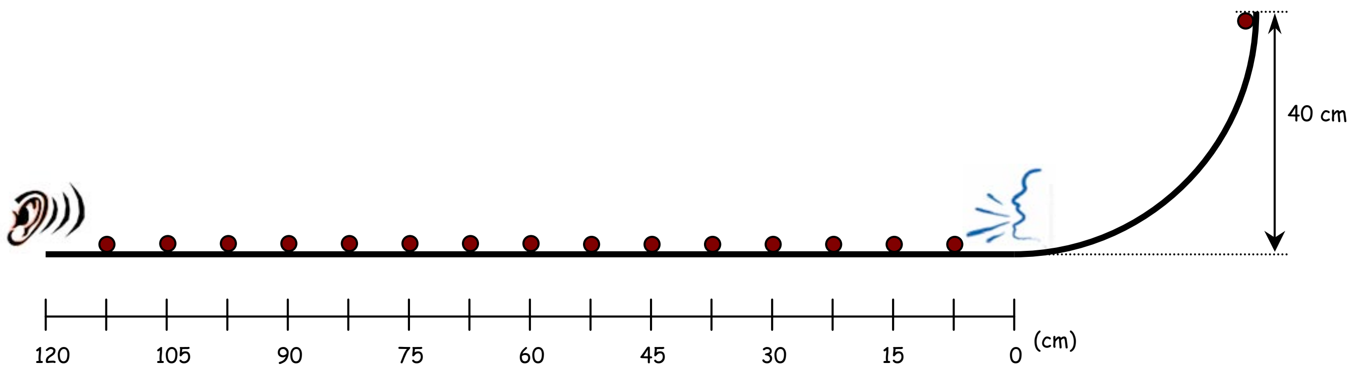
Description

The marble located at the top of the ramp, 40 cm above the floor, has potential gravitational energy. This potential energy is gradually transformed into kinetic energy (motion energy) when the marble hurtles down the slope. **When the marble passes by the mouth, its kinetic energy simulates the sound energy when we shout. Then the marbles hit one another and simulate the motion of air particles when a compression sound wave goes by. Finally, the last marble is projected onto the mastic and stays stuck. This mastic simulates the absorption of the sound energy by the ear.**

Manipulations

1. Install the picture of the mouth at the bottom of the ramp.
2. Install the picture of the ear 60 cm from the mouth.
3. Place 7 marbles at the positions indicated on the diagram above.
4. Hold the 8th marble at the top of the ramp at a height of 40 cm from the floor.
5. Release the 8th marble so it hurtles down the slope and gains speed.
6. Observe the collisions.

Demonstration 2 (The absorption of a sound wave)



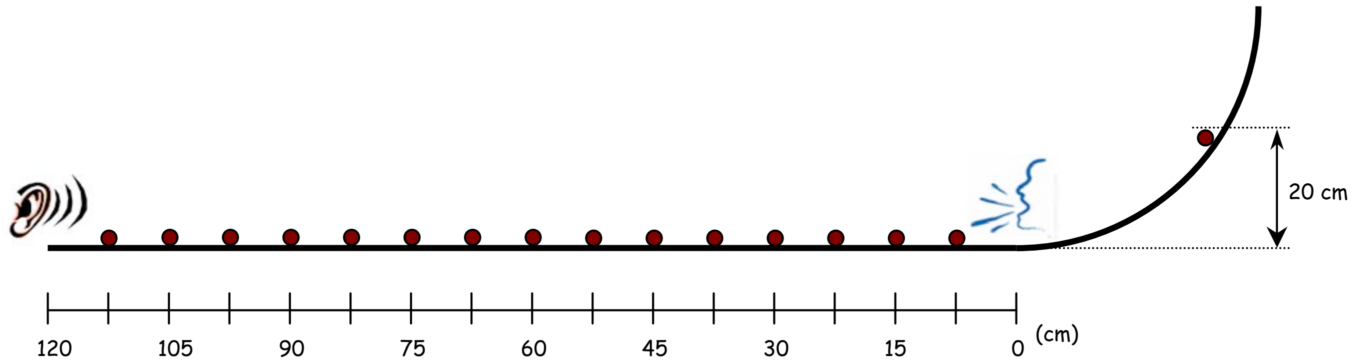
Description

Like the previous demonstration, the marbles hit one another. **With each collision, there is an energy "loss" (energy transformation). Since the path to follow here is longer, the sum of the energy "losses" is too great. The propagation therefore does not reach the ear. A person's shout also has limited reach in the air. Sound energy is dissipated with distance.**

Manipulations

1. Install the picture of the mouth at the bottom of the ramp.
2. Install the picture of the ear 120 cm from the mouth.
3. Place 15 marbles at the positions indicated on the diagram above.
4. Hold the 16th marble at the top of the ramp at a height of 40 cm from the floor.
5. Release the 16th marble so it hurtles down the slope and gains speed.
6. Observe the collisions.

Demonstration number 3 (The energy transported by a sound wave)



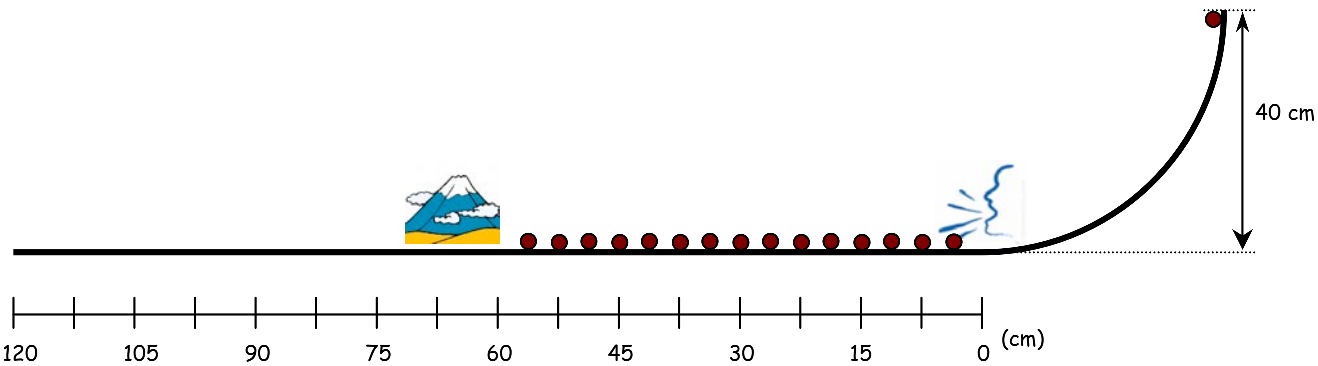
<u>Description</u>

The previous demonstrated is repeated, varying the height at which the marble is released. This height corresponds to the energy transported by the sound wave. **The lower the height at which the marble is released on the ramp, the weaker the simulated sound will be. The propagation of the collisions therefore stops earlier when the marble is released from a height of 20 cm (demo 3) compared to 40 cm (demo 2).**

<u>Manipulations</u>

1. Install the picture of the mouth at the bottom of the ramp.
2. Install the picture of the ear 120 cm from the mouth.
3. Place 15 marbles at the positions indicated on the diagram above.
4. Hold the 16th marble at the top of the ramp at a height of 40 cm from the floor.
5. Release the 16th marble so it hurtles down the slope and gains speed.
6. Observe the collisions.
7. Repeat the manipulations, placing the 16th marble at a height of 20 cm.

Demonstration number 4 (The reflection of a sound wave)



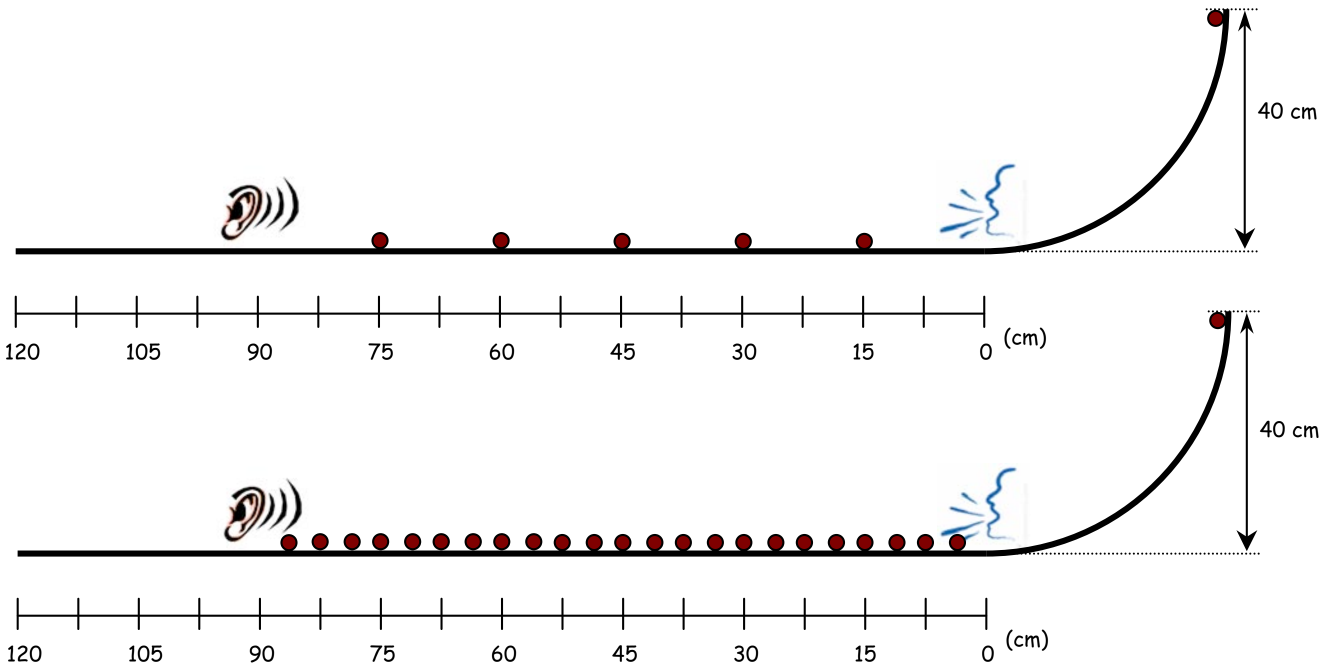
<u>Description</u>

Here, the collisions are propagated from the mouth to the mountain. Then, as with the formation of an echo, the marbles move back in the opposite direction. It is a certainty that the phenomenon of absorption is also felt. Indeed, the echo does not come back to its emitter.

<u>Manipulations</u>

1. Install the picture of the mouth at the bottom of the ramp.
2. Install the solid block of metal with the picture of the mountain 60 cm from the mouth.
3. Place 15 marbles at the positions indicated on the diagram above.
4. Hold the 16th marble at the top of the ramp at a height of 40 cm from the floor.
5. Release the 16th marble so it hurtles down the slope and gains speed.
6. Observe the collisions.

Demonstration number 5 (The speed of a sound wave)



Description

Sound waves can propagate in environments where there are more or fewer particles, namely environments that don't have the same density. **When the particles are close to one another, they don't have far to travel to hit another particle. The speed of sound is therefore greater in environments with greater density. Thus, the collisions propagate more quickly in the case where the marbles are close together.**

Under certain conditions, air may have greater density. This is the case when atmospheric pressure is high (the air particles are closer). Sound therefore travels faster at sea level than at high altitude.

In solids, the density of particles is much higher than in gases. That's why cowboys put their ear to the track to hear if the train was coming. The sound got to them faster and it gave them time to get ready...

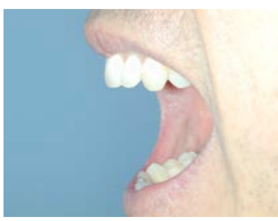
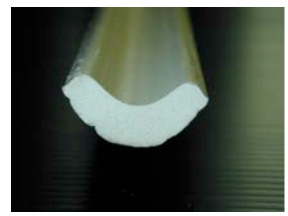
Manipulations

1. Install the picture of the mouth at the bottom of the ramp.
2. Install the picture of the ear 90 cm from the mouth.
3. Place 5 marbles at the positions indicated on the diagram above.
4. Hold the 6th marble at the top of the ramp at a height of 40 cm from the floor.
5. Release the 6th marble so it hurtles down the slope and gains speed.
6. Observe the collisions.
7. Repeat the manipulations using 23 marbles.

To carry out the assembly in class

Necessary materials

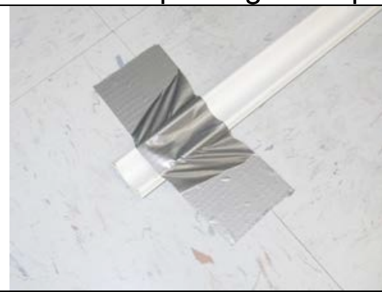
- 1 package of fastening mastic (blue sticky tack)
- 24 traditional glass marbles (about 1.5 cm in diameter)
- 3 pictures: 1 mouth, 1 ear, 1 mountain (see photos 1, 2, 3, below)
- 1 - 8 foot concave quarter-round moulding (see photo 4, below)
- 1 piece of "Duct tape" type adhesive tape
- 1 big, heavy filing cabinet (as a support for our system)
- 1 piece of solid metal (for example a 500 gram mass from a scale)

Photo 1	Photo 2	Photo 3	Photo 4
 	 		

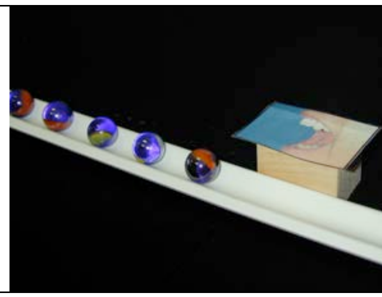
Ramp assembly

1. Jam an end of the quarter round in the second handle of the filing cabinet. The concave part of the quarter round should face up so as to form a ramp in which the marbles will roll.		
		

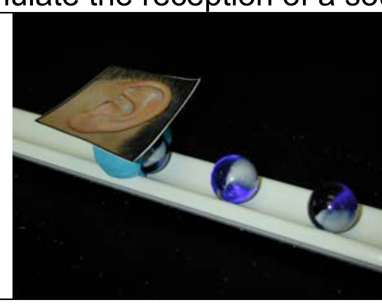
2. Affix the other extremity of the ramp using the tape.



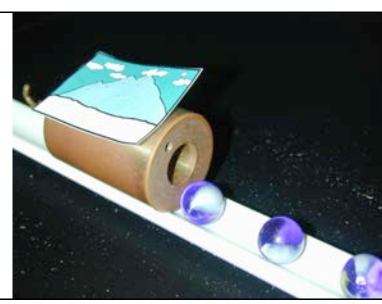
3. Install the mouth at the bottom of the ramp, where the ramp touches the floor. The opening of the mouth must point downward so that a marble hurtling down the ramp seems to be coming out of it. This is our way of simulating the emission of a sound.



4. Install the ear further along the ramp. Its position will vary, depending on the demonstration you are doing. The sticky tack should be shaped so as to hold a marble that collides with it. That is how we simulate the reception of a sound.



5. Finally, during the fourth demonstration, you will have to replace the ear by a mass, simulating a mountain.



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