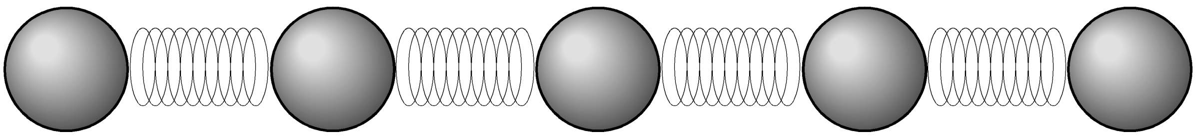
PhyzGuide: The Speed of Sound

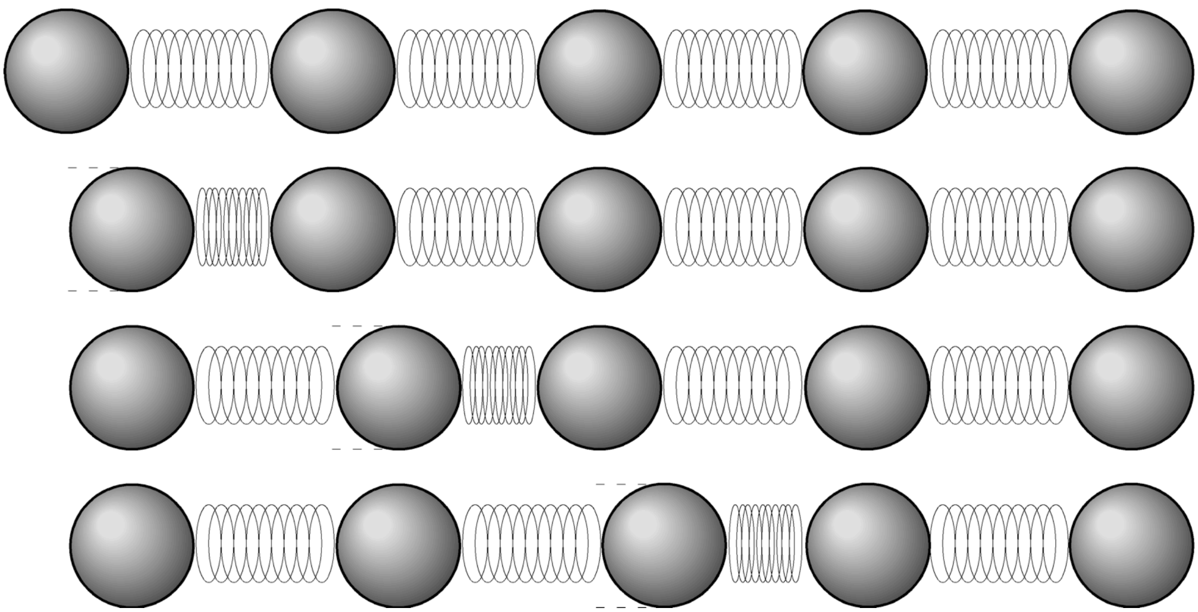
traveling twice the speed of sound, it's easy to get burned...

Waves travel through different substances at different speeds. The speed of a wave is determined only by the substance it's in. Nothing else. But why do waves move so rapidly through beryllium and so much more slowly through air?

Consider a series of identical masses connected by identical springs.



If mass 1 is pushed to the right, it will compress the spring to its right. The compressed spring will exert an increased force on mass 2 to the right, so mass 2 will move to the right. And so on, and so on...



Notice that the rate at which the disturbance advances depends how long it takes for the compression to pass from one spring to the next. Each mass "stands in the way" of this progression, but each mass is moved by the imbalance of spring forces acting on it.

MAKING A DIFFERENCE

In this model, there aren't many elements to vary. But consider what would happen if the springs were stronger. Springs with higher force constants can exert more force with smaller compressions. What effect would this have on the speed of the disturbance?

What if the springs were weaker—what effect would this have on the speed of the disturbance?

What about the masses? Suppose the masses were larger. They would need more force to compel them to accelerate. They would be more sluggish. What effect would this have on the speed of the disturbance?

What if the masses were smaller—what effect would this have on the speed of the disturbance?

SOME ANSWERS

The disturbance will move more rapidly if the springs were stiffer and the masses were smaller. The disturbance will move more slowly if the springs were weaker and the masses were larger. But how does this explain the disparity between beryllium and air? And what about all the other substances?

Adjacent particles in a substance are analogous to masses connected by springs. The masses are the molecules (or atoms) themselves; the springs are the chemical bonds that hold the particles together.

The strength of the bonds (springs) is measured through a quantity called Young's modulus Y. Young's modulus is a fair way of comparing strengths of solids. The mass of adjacent molecules is measured by the density D of the substance. The speed of a disturbance (i.e. *wave speed*) in a substance is proportional to the square root of the ratio of Young's modulus of the substance to its density:

$$v = \sqrt{(Y/D)}$$

The Speed of Sound in Various Substances

State	*Substance*	*Speed: m/s*	*ft/s*	*mi/hr*
Gases	Carbon Dioxide	**259**	850	579
(0˚C)	Air	**331**	1086	740
	Air, 20˚C	**343**	1125	767
	Helium	**965**	3166	2160
Liquids	Ethyl Alcohol	**1207**	3960	2700
(25˚C)	Water (pure)	**1498**	4915	3351
	Sea Water	**1531**	5023	3425
Solids	Lead	**1200**	3937	2684
	Wood (mahogany)	**~4300**	~14,100	~9600
	Iron	**5000**	16,400	11,190
	Aluminum	**5000**	16,400	11,190
	Glass (pyrex)	**5170**	17,000	11,570
	Steel	**5200**	17,100	11,630
	Granite	**6000**	19,700	13,420
	Beryllium	**12,900**	42,300	28,860

