Chapter 1: The Fundamental Physical Quantities

Welcome to the *Acoustics Terminology for Musicians* podcast, brought to you by your host, Robert Willey. The order that the terms are introduced in this podcast follows the organization of John Backus' book, The Acoustical Foundations of Music.

[image: BackusCover.png]

Part I of Backus' book is called "The Physical and Acoustical Background", and consists of four chapters. The first chapter is titled "The Fundamental Physical Quantities". Backus says that we need to learn some basic terms from physics that we will then be able to use as we continue in our study of acoustics.

[image: NonMetricSystemCountries.png (public domain)]

The **metric system** began around 1800 in France in order to make computation easier and to facilitate trade. It has since been adopted by most countries besides the United States and Canada.

The metric system makes it easier to do computations since all units, such as meter and kilogram can be evenly divided by ten, unlike the Imperial units of feet and pounds. A meter is a little longer than a yard, and there are about two and half centimeters to an inch. One kilogram is equal to about 2.2 pounds.

[image: AirMoleculeEquilibrium.png]

The **displacement** of an object is the distance it has been pushed. When a pressure wave moves through the air it temporarily displaces the air molecules it passes through by pushing them away from their resting point, or point of **equilibrium**.

Speed and **velocity** both have to do with how fast an object moves. Speed is the distance an object has moved in a unit of time, while velocity measures an object's speed *and* the direction it is moving in.

[image: SpeedFormula.png]

Speed can be computed by dividing distance by time, like we do when we calculate how many miles per hour a car is travelling. When someone tells you that a car travelled 60 miles per hour you don't know which direction it went.

[image: DistanceFormula.png]

If we divide both sides by Speed, and multiply both sides by Time, we get the formula Distance = Speed / Time.

The **mass** of an object is the amount of matter in it. The metric system's unit of measure of mass is the kilogram, which is equal to about 2.2 pounds. A kilogram was originally defined as equal to the mass of 1,000 cubic centimeters of water. The more mass an object has, the more it resists changes in speed or position when a force is applied to it.

[image: EinsteinEquation.png]

Einstein figured out that mass can be converted to energy, and his Special Theory of Relativity expresses the relationship between energy, mass, and the speed of light in the equation E = mc squared. The sun creates energy by converting hydrogen into helium.

[image: Gravity.png]

The force of gravity on a mass can be measured by an object's **weight**. Gravity on earth is six times greater than on the moon, so a one-kilogram object will weigh six times more on earth than it does on the moon, while its mass remains the same in both locations.

Force is a push or pull on an object. When we use force on an object it may change, or **distort**, its shape. If the object is **elastic** enough it will stretch, and return to its original shape after we stop applying force to it.

[image: Friction.png]

Newton's First Law states that an object at rest remains at rest unless acted upon by a force. Force must be applied to get an object moving, and to overcome any friction between it and others it is touching. Friction may then continue to act to slow it down as the object rubs against its environment.

[image: NewtonFormula.png]

Force is measured in newtons. A one newton force will cause a one-kilogram mass to accelerate to one meter per second squared, or less, depending on how much friction there is.

[image: PressureFormula.png]

Pressure is measured by the number of newtons of force on an area. The unit of pressure is newtons per square meter.

Gravity pulling down on the atmosphere above us creates a pressure on us of almost 100,000 newtons per square meter, or about 15 pounds per square inch. Like fish that are unaware of the water they swim through, we live in a pressurized world, and most of what we study in acoustics are phenomena resulting from pressure waves, which need a medium like air to travel through.

[image: EustachianTube.png (PD)]

You can feel pressure differences between your middle ear and your environment when you go up in an airplane or dive deep underwater. It can be equalized by opening the Eustachian tube leading from your middle ear to your pharanx by swallowing, sneezing, or yawning, which opens the tube.

[image: IsaacNewton.png comes from Wellcome Images, a website operated by Wellcome Trust, a global charitable foundation based in the United Kingdom]

Newton's First Law of Motion states that an object at rest will remain at rest unless acted upon by an external force. **Work** is the amount of force applied to an object times the distance it travels.

[image: OneJouleOfWork.png]

Energy is measured in terms of the unit joule. One joule of work is done when one newton of force is used to accelerate an object through a distance of one meter in one second. Work that is done to overcome friction generates heat. Try rubbing your hands together to make them warmer. If you apply more pressure between your hands you will create more friction, and therefore more heat will be generated. Pressure waves gradually lose their energy as they push their way through air molecules and bounce off walls.

[image: EnergyConversion.png from Creative Commons 4.0 license, https://www.e-education.psu.edu/egee102/node/1906]

Doing work requires **Energy**. Energy cannot be created or destroyed, it can only be converted from one form to another. Acoustic energy is the energy that passes through a medium in the form of a wave.

Power is the rate at which work is done, and is measured in joules per second, or watts. Something that is using energy at a rate of one joule per second is using power at the rate of one watt.

[image: Lightbulb.png Daderot donated this photo of a 100,000 watt lightbulb to the public domain. Museum of Science and Industry (Chicago)]

A one-hundred watt lightbulb uses one hundred joules of energy per second. A kilowatt is equal to a thousand watts, and y our electric bill is calculated by the number of kilowatts you use in a month times the number of hours you use them. A kilowatt of power used for one hour costs about 15 cents.

[image: PressureWaveToEars.png Images from Anatomy & Physiology by OpenStax are licensed under CC BY. https://open.oregonstate.education/aandp/chapter/15-3-hearing/]

We have reached the end of the vocabulary covered from Chapter 1. In Chapter 2 we will apply these terms to describe simple vibrating systems. Vibrations create pressure waves, which travel through the air and enter a listener's ears, which then cause sensations of sound in their brain.