ACOUSTIC IMPEDENCE

MU610A: ACOUSTICS & PSYCHOACOUSTICS

EDWARD COSTELLO

FUNDAMENTAL ITEMS

- Relationship between velocity and pressure
- Acoustic impedance
- Potential and kinetic energy in a sound wave

PERIODIC WAVEFORMS

- Periodic waveforms all have the following parameters: Period, rate of rotation(frequency), wavelength, amplitude and starting position or phase.
- Frequency is the rate of repetition per unit time. It is measured in cycles per second, or Hertz (Hz)
- Frequency, velocity and wavelength are related by the following formula:

$$v = f\lambda$$

PERIODIC WAVEFORMS

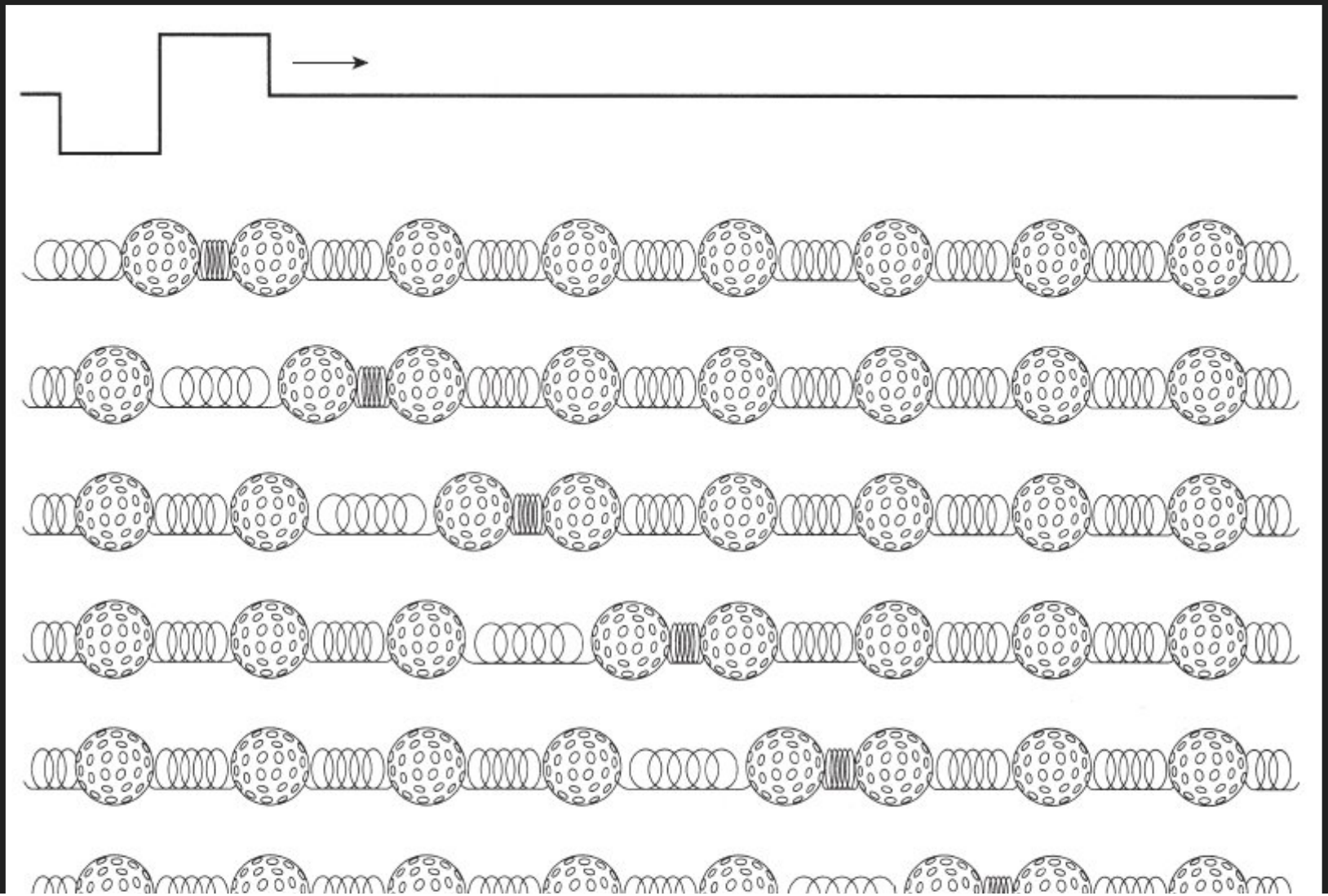
- Amplitude refers to the amount of deviation/difference from the normal state of the medium. In the case of sound waves, it will refer to the change in air pressure (remember how the 'wave' is used to outline maximum/ minimum pressure in the disturbance of the medium).
- The Sine wave is the simplest form of wave and can be used as building blocks for more complex waves.
- Phase, or phase offset is the starting point of a wave

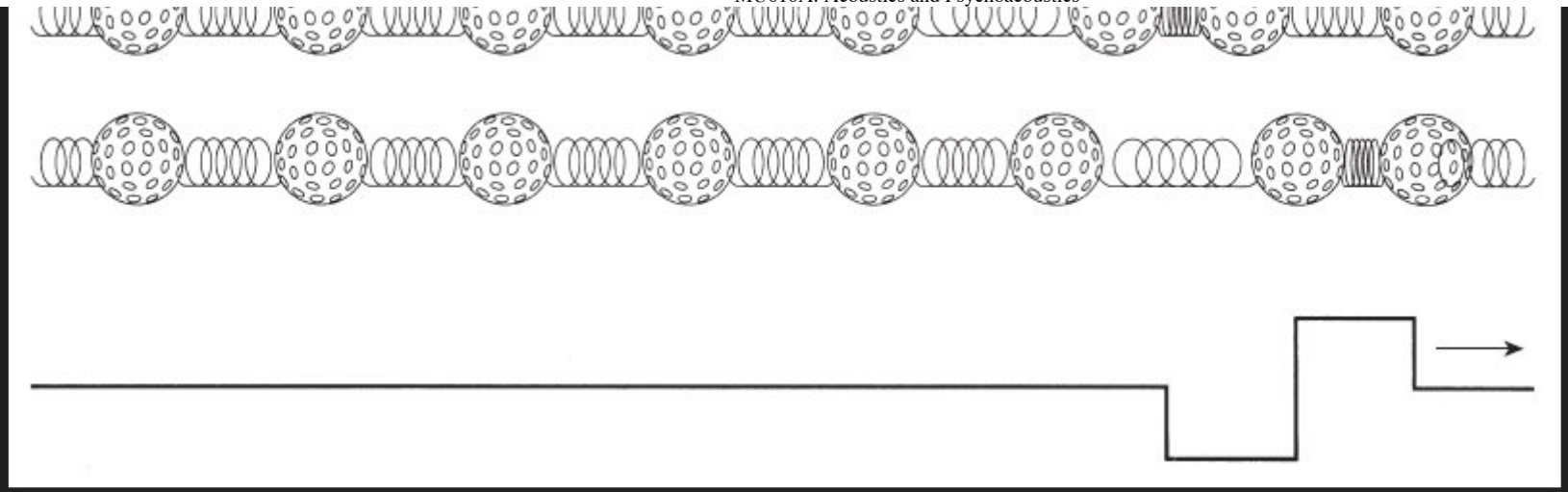
VELOCITY

- As we have seen already a propagating wave can be seen as a series of compressions and rarefactions which are traveling through a medium.
- In order for this occur, each molecule in the medium must move closer together and further apart.
- This implies that a velocity is involved in the process.

VELOCITY

- Consider the golf ball and spring model, the balls must move to get closer together.





VELOCITY

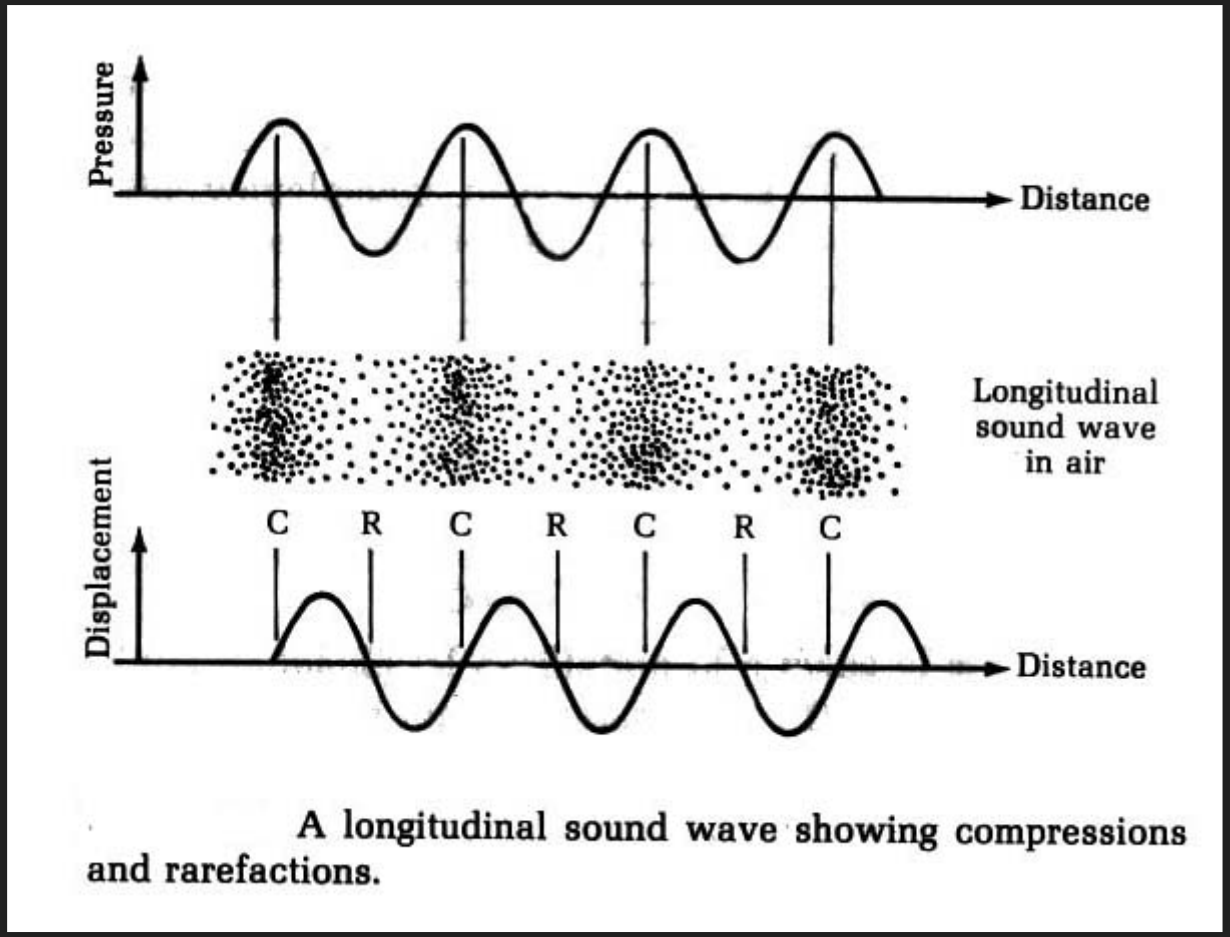
- This velocity component will be zero when the molecules are at their maximum closeness (compressions) and separation(rarefactions), as the molecules will be stationary.
- Midway between these points the velocity will be maximum in one direction.
- Reaching the other extreme, the molecules will slow down to zero, before the process is repeated again.

So...if velocity is at a minimum when the molecules are closest together...what does this tell us about the relationship between velocity and pressure?

PRESSURE

- When the velocity is maximum, the molecules will be at average pressure: in between rarefactions and compression
- When velocity is zero, pressure will be at its maximum (compression), or minimum (rarefaction)
- These two sides of the propagation phenomena are called the velocity component and pressure component.
- Depending on the medium, these components will have different amplitudes.

PRESSURE



A longitudinal sound wave showing compressions and rarefactions.

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- Velocity has a direction, as the molecules are moving from one position to another. The velocity component gives a sound wave its direction.
- Pressure, however is measured at a point, it is a scalar quantity with no directional properties. It goes up and down.

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- Note that for a sine wave pressure component, the velocity component will be a cosine wave(as seen in the previous diagram).
- A cosine wave occurs $\frac{1}{4}$ cycle earlier than the corresponding point on the sine wave. It is 90 degrees offset to the sine wave.

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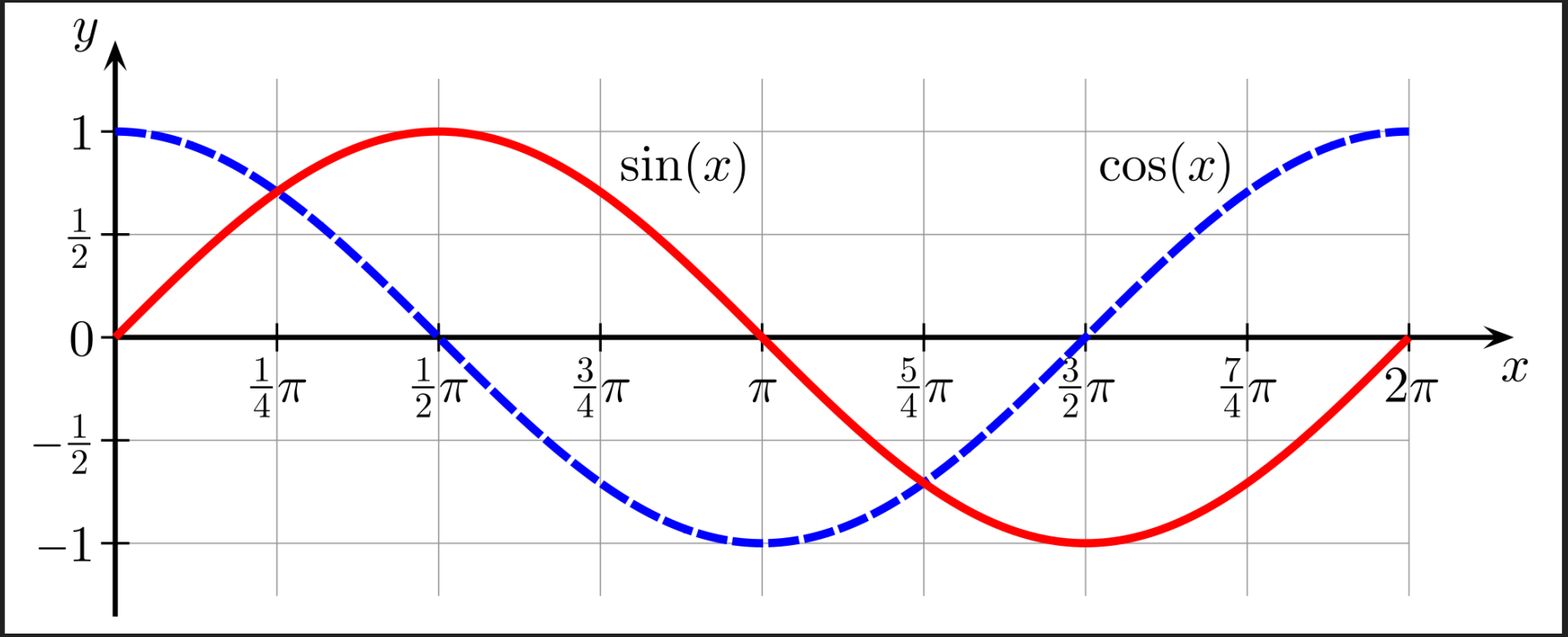

ACOUSTIC IMPEDENCE

- Acoustic Impedance is a measure of the resistance of the medium to the propagation of a sound wave.
- Velocity and pressure components of a sound wave are closely related
- For a given pressure amplitude, a low density medium will have a higher amplitude velocity component. A more dense medium will have a lower velocity component

ACOUSTIC IMPEDENCE

- The ratio between the amplitudes of these two components is called the Acoustic Impedance of the medium. It is constant for a particular medium. If the pressure component amplitude rises, the velocity amplitude will fall.

ENERGY COMPONENTS OF A SOUND WAVE

- We have just looked at the velocity and pressure components of a sound wave, however another aspect of sound wave propagation arises when the energy within the pressure and velocity components is analysed.
- The compression/rarefaction of the medium is similar in certain respects to compressing or expanding a spring. This is a form of potential energy (ie. energy 'stored' in the system/the energy that can potentially be delivered)

ENERGY COMPONENTS OF A SOUND WAVE

- On the other hand when the molecules in the medium are moving they have kinetic energy: energy delivered in motion.
- When pressure is maximum, the potential energy is maximum, this potential energy is delivered as kinetic energy.
- When the velocity is maximum, the potential energy is zero, and the kinetic energy is maximum.

SUMMARY

- Sound waves have Velocity and Pressure components.
- When the velocity is maximum, the molecules will be at rest position: average pressure compressions and rarefactions.
- When velocity is zero, pressure will be at its maximum (compression) or minimum (rarefaction)
- The ratio between the amplitude of these two components is called the Acoustic Impedance of the medium.

SUMMARY

- Acoustic Impedance is a measure of the resistance of the medium to the propagation of a sound wave.
- Acoustic Impedance is constant for a particular medium.
- A sound wave can also be understood as a constant energy system, consisting of potential and kinetic energy.