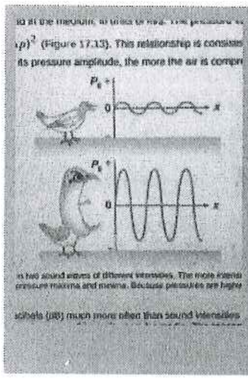


Physics 20 Unit D: Mechanical Waves

$v = f\lambda$

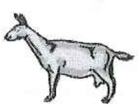
The Universal Wave Equation

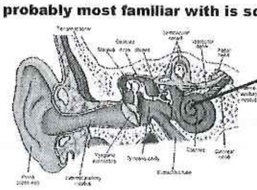
POS Checklist:

- ☐ describe how the speed of a wave depends on the characteristics of the medium.
- ☐ predict, quantitatively, and verify the effects of changing one or a combination of variables in the universal wave equation ($v = f\lambda$)

The Speed of a Wave

We will discuss many different types of mechanical waves in P20, but one you are probably most familiar with is sound.





So, what detemines the speed of a sound wave?

Sound (like any other mechanical wave) must have a medium (matter) to move through.

Sound waves are transmitted from particle to particle in the medium: one particle bumping into its neighbour, until the wave has moved from source to observer.

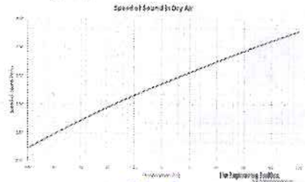
The speed of any wave depends on the medium it travels through.

Sound travels through solids, liquids and gases at different speeds. As you can see from this table, sound moves fastest through solids, slowest through gases.

Table 12.1: Speed of sound in different media at 25 °C

State	Substance	Speed in m/s
Solids	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass (Flint)	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

For gases, the speed of a wave is roughly proportional to temperature of the gas and inversely proportional to the mass of the gas particles.



Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

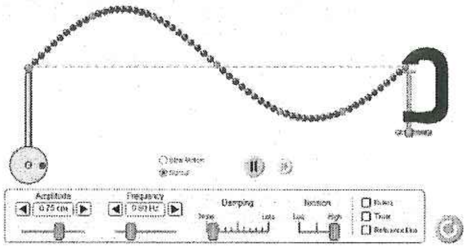
Higher T = higher **speed** **Higher mass =** slower **speed**

For liquids and gases, speed is related to the density and type of material (although there is not an easy to think of relationship).

Review: Predictions about Waves

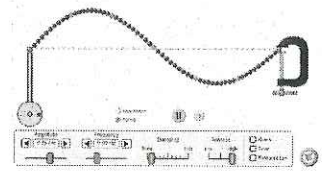
If we keep velocity constant, what will happen as we change wavelength and frequency?

https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html



Review: Predictions about Waves

If we keep velocity constant, what will happen as we change wavelength and frequency?



https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html

From the animation, we see that:

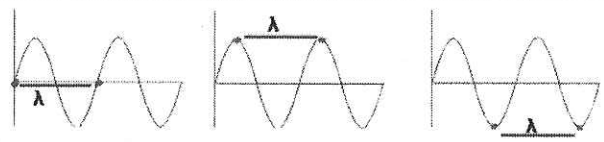
f is _inversely_ **proportional to λ.**

Universal Wave Formula

Waves will move in straight lines at constant speed. This means we can describe the motion of a line with :

$$v = \frac{d}{t}$$

But what is the distance and time of a wave?



For displacement, we measure the wavelength, λ, of the wave. This is the distance, in m, between any two repeating parts of the wave.

For time, we will use period, T, the amount of time it takes for the wave pattern to repeat.

So: $v = \frac{d}{t}$ **therefore:** $v = \frac{\lambda}{T}$ **and as:** $\frac{1}{f} = T$

$$v = f\lambda$$

the Universal Wave Eqn.

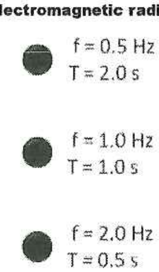
where:

v = velocity (m/s)

f = frequency (Hz or s^{-1})

λ = wavelength (m)

The universal wave eqn works for any wave, from sound to water waves to light. The unit for frequency in this formula, the hertz, is named after Heinirich Hertz, the German physicist who first confirmed the existance of electromagnetic radiation (radio waves).



Recall that the hertz is the same as 1/s due to the formula:

$$f = \frac{1}{T}$$

$\lambda = 0.790\,m$

ex) Determine the frequency of a 790 mm wavelength wave travelling at 520 m/s.

$v = f\lambda \quad 520\,m/s = f(0.790\,m)$

$f = \underline{658\ Hz}$

ex) Radio waves travel at 3.00×10^8 m/s. Determine the wavelength of your favorite radio station (AM is in kHz, FM is in MHz).

for ⇒ AM 1260

$f = 1260\ kHz = 1260000\,Hz$

$v = f\lambda$

$3.00 \times 10^8\,m/s = (1260000\,Hz)\,\lambda$

$\lambda = \underline{238\,m}$

300 s   λ

ex) While floating in a tube on a lake, you notice that you bob up and down 4.0 times every 5.0 minutes. You estimate that the distance between the crests is 4.0 m. What is the estimated speed of the waves?

$\frac{4\ \text{up \& downs}}{300\,s} = \frac{0.01\overline{3}\ \text{up \& downs}}{1\,s} = f$

$v = f\lambda$

$v = (0.01\overline{3}\,Hz)(4.0\,m)$

$v = \underline{0.053\,m/s}$

ex) A wave has a wavelength of 4.0 m. If the frequency of the wave increases by a factor of 5, and the speed of the wave decreases by a factor of 7, determine the next wavelength.

$v = f\lambda$

$(\frac{1}{7}) \propto (5)\lambda$

$\frac{1}{35} \propto \lambda$

$\lambda = 4.0\,m \times \frac{1}{35} = \underline{0.11\,m}$

ex) A wave has a wavelength of 6.0 m. If the period of the wave decreases by a factor of 3, determine the new wavelength of the wave.

Step 1

$f = \frac{1}{T}$

$f \propto \frac{1}{(\frac{1}{3})}$

$f \propto 3$

Step 2

$v = f\lambda$

$(1) \propto (3)\lambda$

$\frac{1}{3} \propto \lambda$

Step 3

$\lambda = 6.0\,m \times \frac{1}{3} = \underline{2.0\,m}$

Practice: Waves UA