

## CONCEPT: SPEED OF LONGITUDINAL WAVES IN FLUIDS AND SOLIDS

- Just like transverse waves, the **speed** of longitudinal waves depends *only* on the properties of the **medium**:

### TRANSVERSE

$$v_{string} = \sqrt{\frac{F_T}{\mu}} = \lambda f$$

### LONGITUDINAL

For **FLUIDS**:

$$v_{long.} = \sqrt{\frac{\beta}{\rho}} = \lambda f$$

$\beta$  = bulk modulus of fluid

$\rho$  = density of fluid

In **SOLIDS**:

$$v_{long.} = \sqrt{\frac{Y}{\rho}} = \lambda f$$

$Y$  = Young's modulus of solid/rod material

$\rho$  = density of solid

EXAMPLE: In a liquid of density 1200 kg/m<sup>3</sup>, longitudinal waves with a frequency of 400Hz have a wavelength of 8m. Calculate the bulk modulus of the liquid.

EXAMPLE: You strike a 60.0-m-long brass at one end. How long does it take for a person on the other end of the rod to hear the sound? The Young's Modulus of brass is  $9 \times 10^{10}$  Pa and the density is 8600 kg/m<sup>3</sup>.

**PROBLEM:** A metal bar has a length of 1.5m and a density of 6400 kg/m<sup>3</sup>. Sound waves take 3.9×10<sup>-4</sup>s to travel along the length of the bar. What is the Young's modulus for this metal?

- A) 2,311 Pa
- B) 9.47×10<sup>10</sup> Pa
- C) 2.46×10<sup>7</sup> Pa
- D) 3.744 Pa

| WAVES                           |                            |
|---------------------------------|----------------------------|
| $v = \lambda f$                 | (all waves)                |
| $v = \sqrt{\frac{F_T}{\mu}}$    | (for <i>strings only</i> ) |
| $v = \sqrt{\frac{\beta}{\rho}}$ | (long. waves in liquids)   |
| $v = \sqrt{\frac{Y}{\rho}}$     | (long. waves in solids)    |

**PROBLEM:** In a container, 32 g of oxygen occupies 0.0224 m<sup>3</sup>. If the speed of sound in this container is 317 m/s, what is the bulk modulus for oxygen gas?

- A) 1.44×10<sup>8</sup> Pa
- B) 453 Pa
- C) 1.44×10<sup>5</sup> Pa
- D) 7.03×10<sup>4</sup> Pa

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