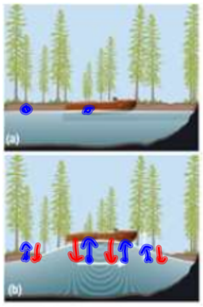
SPH3U 8.1 Vibrations

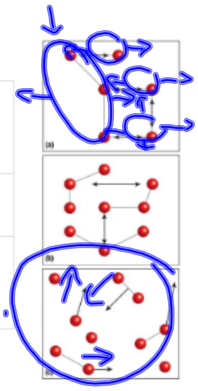
1. Vibrations and mechanical waves

Vibration:	cyclical motion about an equilibrium.
equilibrium	middle point or rest position.
Mechanical wave:	transfer of energy through a medium by vibration
medium	the material that is vibrating
net motion	the displacement of a particle in the medium; this is normally ∅.



2. Particle behaviour in different media

Waves in solids:	very efficient at transmitting waves → waves go far and fast.
elastic material	medium that retains its original shape.
Waves in fluids:	(liquids & gases) less efficient. liquids > gases. gases: waves use mostly translational movement.



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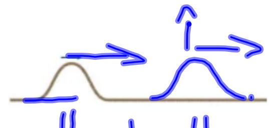
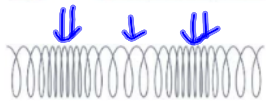
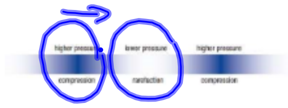
SPH3U 8.2 Types of Mechanical Waves

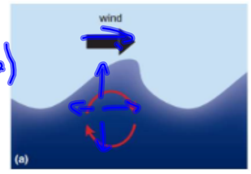
1. Types of waves

① Transverse wave:	vibration is perpendicular to the direction of energy flow.
② Longitudinal wave:	vibration is parallel to the direction of energy flow.
waves in gases	(i.e. sound) longitudinal. involve compression and rarefaction.
sound	longitudinal. air is vibrating forward and backward. (in solids, it's also transverse)
complex wave motion	transverse + longitudinal at the same time.









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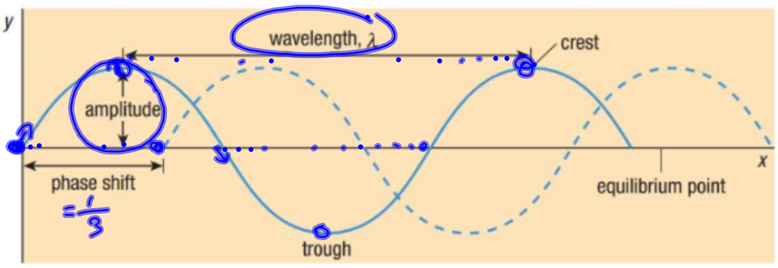
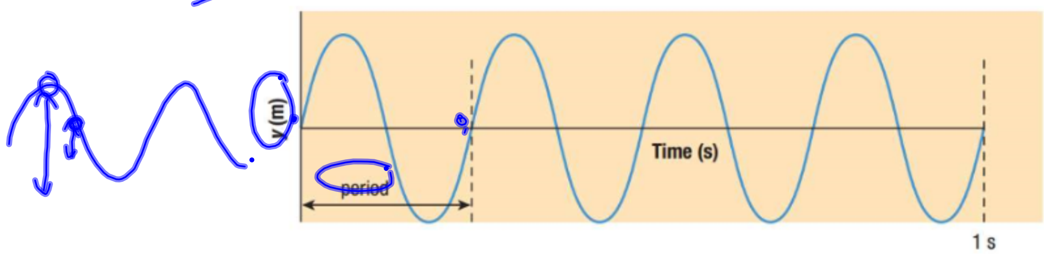
SPH3U 8.3 Wave Characteristics

1. Geometric wave characteristics (Freeze time - look at one single instant).



Amplitude:	max distance from equilibrium. $A = \frac{max - min}{2}$.
λ Wavelength:	distance between 2 similar points in 2 cycles. (Units: m).
Phase:	x-coordinate of a unique point. (Units: m or proportion)
Phase shift:	a shift in the x-axis relative to another value. (Units: m or proportion)

2. ~~Geometric~~ Time-based. wave characteristics (one specific location over time)



Period: T	the time for a vibrating particle to complete 1 cycle (s).	
Frequency: f	the number of cycles per second.	
equation	$f = \frac{1}{T}$ Units: Hz $(\frac{1}{s})$	$T = \frac{1}{f}$ Units: s.
Wave speed:	$v = \frac{\lambda}{T}$ Units: m/s.	$v = f\lambda$
equation	how fast a wave travels through a medium.	

Simple harmonic motion (SHM):	any motion that repeats itself at regular intervals.

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SPH3U 8.4 Determining Wave Speed

1. The universal wave equation

Universal wave equation:	$v = f\lambda$.	$\left(v = \frac{\lambda}{T},\ T = \frac{1}{f}\right)$

A harp string supports a wave with a wavelength of 2.3 m and a frequency of 220.0 Hz. Calculate its wave speed.

$v = f\lambda = (220)(2.3) = 506\ m/s.$

A trumpet produces a sound wave that is observed travelling at 350 m/s with a frequency of 1046.50 Hz. Calculate the wavelength of the sound wave.

$v = f\lambda.$

$\lambda = \frac{v}{f}$

$\lambda = \frac{350}{1046.5} = 0.33\ m.$

2. Factors that affect wave speed

Rigidity:	how rigid the medium is: more stiff = faster wave.
Temperature:	(in gas) as the temperature ↑, wave speed ↑
Linear density:	(in strings) mass per unit distance
equation	$\mu = \frac{m}{L}$, where μ is linear density
Speed of a wave on a string:	$v = \sqrt{\frac{F_T}{\mu}}$ (F_T: tension force).

On your class wave machine, you have a string of mass 350 g and length 2.3 m. You would like to send a wave along this string at a speed of 50.0 m/s. What must the tension of the string be?

$v = \sqrt{\frac{F_T}{\mu}} \rightarrow v^2 = \frac{F_T}{\mu} \rightarrow F_T = \mu v^2$

$\mu = \frac{m}{L}$

$F_T = \frac{mv^2}{L} = \frac{(0.35)(50)^2}{2.3} = 380\ N.$

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SPH3U 8.5 Properties of Sound Waves

1. Categories of sound waves

Audible sound waves:	we can hear f between 20 Hz - 20 kHz.
infrasonic	below our hearing, f < 20 Hz. earthquakes.
ultrasonic	above our hearing, f > 20 kHz.

2. The speed of sound through air

Equation:	$v_s = 331.4\ m/s + (0.606 \frac{m}{s\,°C})T$

The temperature outside is 23 °C. What is the speed of sound in air at this temperature?

$v_s = 331.4 + 0.606(23) = 345\ m/s.$

If the speed of sound is measured to be 318 m/s, what is the current air temperature?

$v_s = 331.4 + 0.606T \quad T = \frac{v - 331.4}{0.606} = \frac{318 - 331.4}{0.606} = -22.1°C.$

3. Mach number

Mach number:	ratio of airspeed to the local speed of sound.
equation	$M = \frac{v}{v_s}$ $\left(M = \frac{\text{airspeed of object}}{\text{speed of sound}}\right)$

An aircraft is flying at 905 km/h in air at the temperature −50.0 °C. Calculate the Mach number associated with this speed.

$M = \frac{v}{v_s}$

$v_s = 331.4 + 0.606(-50)$

$= 301.1\ m/s.$

$v = 905 \frac{km}{h} \times \frac{1000\ m}{1\ km} \times \frac{1\ h}{3600\ s} = 251.4\ m/s.$

$M = \frac{251.4}{301.1} = 0.835$ ∴ the Mach number is 0.835.

4. Sound intensity

I Sound intensity:	amount of sound energy transferred per unit area.
β sound level	perceptual loudness of sound, in dB.

Type of sound	Typical sound intensity (W/m²)	Sound level (dB)	Type of sound	Typical sound intensity (W/m²)	Sound level (dB)
threshold of human hearing	1×10^{-12}	0	jet flyover (at 300 m)	1×10^{-2}	100
normal breathing (at 1 m)	1×10^{-11}	10	rock band	0.1	110
typical whisper (at 1 m)	1×10^{-10}	20	jet aircraft engine (at 80 m), power saw	1.0	120
empty classroom	1×10^{-9}	30	threshold of pain	10	130
computer (at 1 m)	1×10^{-8}	40	military jet taking off	100	140
library	1×10^{-7}	50	space shuttle (at 180 m)	316	145
alarm clock (at 1 m)	1×10^{-6}	60	sound cannon (at 1 m)	1 000	150
vacuum cleaner (at 2 m)	1×10^{-5}	70	1 tonne TNT (at 30 m) (buildings 50 % destroyed)	380 000	175.8
diesel locomotive (at 30 m)	1×10^{-4}	80	tornado	1×10^{12}	240
motorcycle (at 10 m)	1×10^{-3}	90	atomic bomb	1×10^{13}	250

Loudness and distance:

Distance (m)	Sound level (dB)
1	120
10	100
50	86
100	80
200	74
500	66
1 000	60
2 000	54
5 000	46
10 000	40

Sound safety:

Continuous dB	Permissible exposure time
85	8 h
88	4 h
91	2 h
94	1 h
97	30 min
100	15 min
103	7.5 min
106	3.75 min (<4 min)
109	1.88 min (<2 min)
112	0.94 min (~1 min)
115	0.47 min (~30 s)

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