

# **PHYS1406: Physics of Sound and Music**

**Spring 2021**

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# Topics we'll cover this semester

- Preliminaries: Basic math, music, and physics terminology
- Physics of oscillations and waves
- Production of sound (instruments and voice)
- Perception of sound (hearing, loudness, pitch & timbre)
- Auditorium and room acoustics; electrical reproduction of sound
- Musical scales and tuning systems (standardization of musical notes)

**Why are you in this class?**

**What questions about sound & music would you like to know the answer to?**

# What is sound? What differentiates speech, music, & noise?

- Sound is a **pressure wave** in air (or some other medium, which could be a liquid or solid).
- The pressure wave consists of alternating regions of **compression** and **expansion** of the air molecules.
- **Energy is transferred** from the source of sound to our ears, while the individual air molecules just oscillate back-and-forth in place.
- noise: chaotic, unorganized sound
- speech & music: organized sound
- **musical notes** have a **definite pitch** (low or high), while noise does not

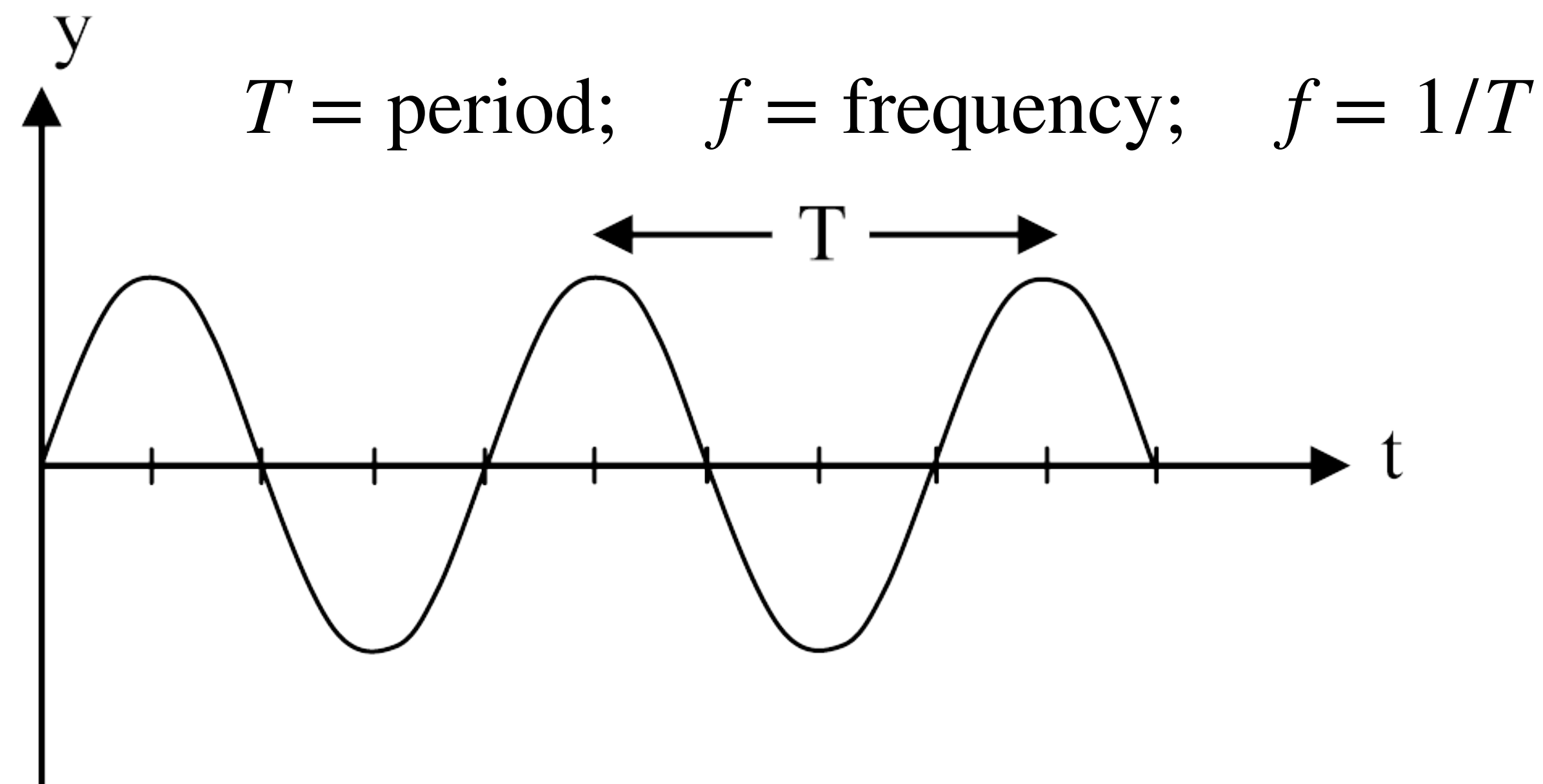
# Demos: sound measuring devices & musical instruments

- Measuring devices
  - **oscilloscope**: shows how the sound pressure wave changes in time
  - **FFT analyzer**: shows how much sound energy is associated with different pitch components
  - **spectrogram**: shows how the pitch content of a sound changes in time
- Musical instruments and sound-making devices:
  - whistle, singing, speaking
  - penny whistle, recorder, funny plastic recorder, train whistle, other wind instruments
  - plucked guitar string, bowed violin string
  - bell, drum, shakers, marimba bar, other percussion instruments
  - ratchet, crumpled paper, applause

# Range of human hearing

<https://www.szynalski.com/tone-generator/>

- Normal range: 20 Hz - 20,000 Hz
- What is frequency? Number of repetitions (oscillations, cycles, ...) in a given time interval
- Example: Heart rate: 70 beats/1 minute = 1.14 beats/sec
- Hertz (Hz): 1 Hz = 1 cycle/sec



# 1. Preliminaries

# Basic math review

- Entering numbers on a calculator: What's the value of  $1/2\pi$ ?
- Fractions: What's the value of 2 divided by  $3/2$ ?
- Powers (exponential notation): What's the value of  $2^4$ ?  $10^3$ ?  $10^{-2}$ ?

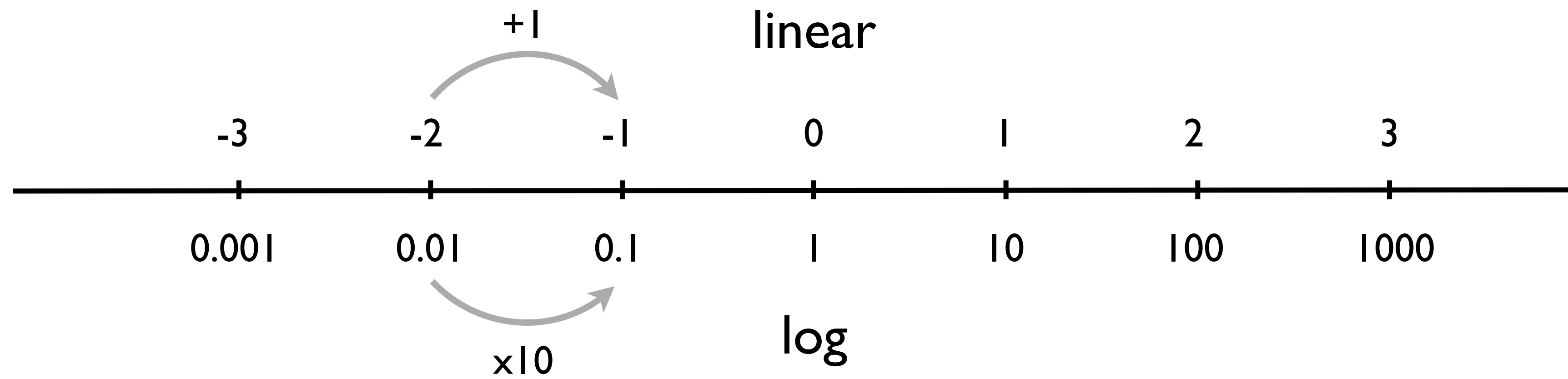
- Prefixes:

nano	micro	milli	centi	kilo	mega	giga	tera
$10^{-9}$	$10^{-6}$	$10^{-3}$	$10^{-2}$	$10^3$	$10^6$	$10^9$	$10^{12}$

- Comparing two numbers: Compare the heights of two people, one who is 5.5 ft tall versus another who is 72 inches all.
- Converting units: The speed of sound in air at room temperature (25 celsius) is 346 m/s. What is its value in ft/s? miles/s?



# Linear vs logarithmic scales

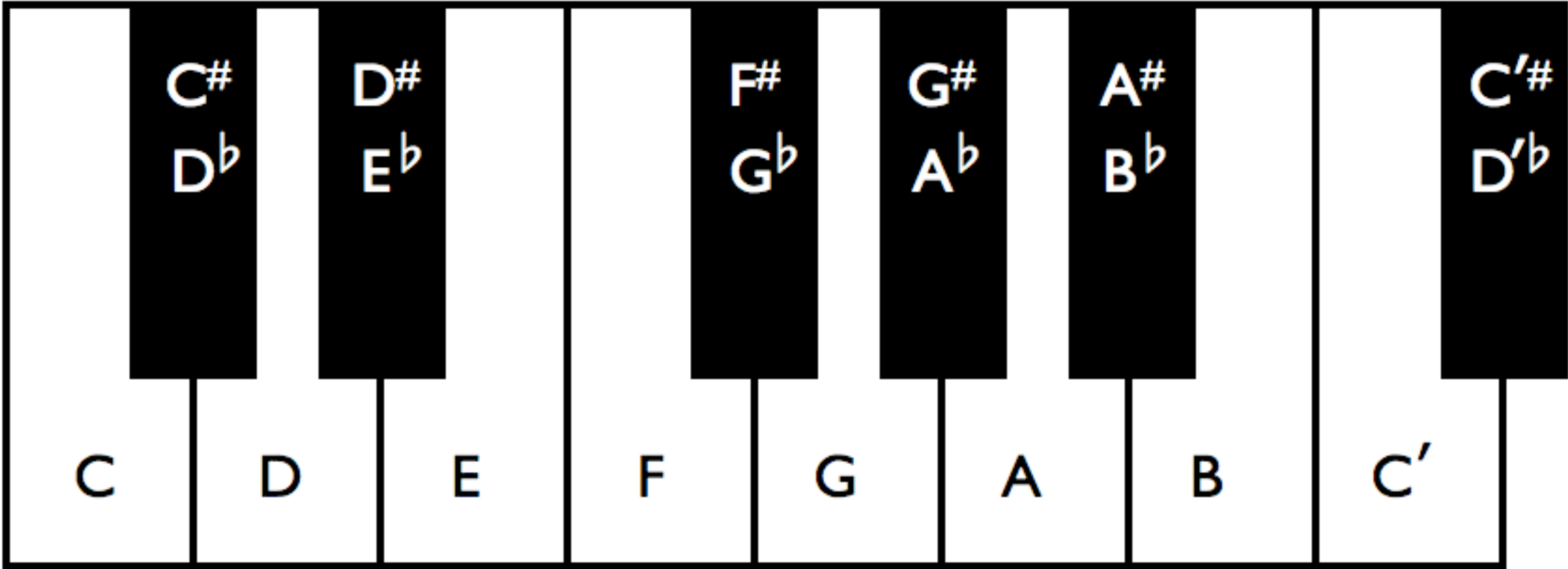


# Music terminology

- Pitch:
- Timbre:
- Octave:
- Chromatic, diatonic, and pentatonic scales:
  - <https://www.youtube.com/watch?v=jaMA8LWW3C0> (pentatonic scale)
- Equal temperament:
- Musical intervals:
  - fifth, fourth, major third, minor third
- Chord:

# Chromatic and diatonic scales

C - C# - D- Eb - E - F - F# - G - Ab - A- Bb - B - C'



do – re – mi – fa – sol – la – ti – do

# Physics terminology

- Position, displacement:
- Time, duration:
- Velocity, speed, acceleration:
- Force, mass, Newton's 2nd law:
- Density, pressure:

# Exercise

- Calculate the pressure exerted by a 120 lb woman standing on the floor, wearing stilettos having approximately circular heels with radius 0.25 in. Compare to the pressure exerted by a 10,000 lb elephant whose four feet are approximately circles with radius 10 in.