Resonance and Damping

To know what free and forced vibration are and the phase difference between the driver and driven
To know what resonance is and how it is reached
To know what light, heavy and critical damping are and their effects on resonance

Free Vibration

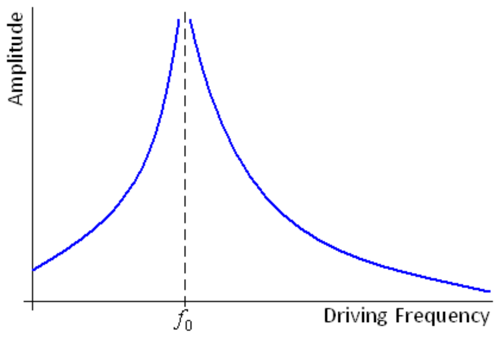
Free vibration is where a system is given an initial displacement and then allowed to vibrate/oscillate freely. The system will oscillate at a set frequency called the natural frequency, f_0. We have seen from the last lesson that the time period for a pendulum only depends on the length and gravitational field strength whilst the time period of a mass and spring only depends on the mass and the spring constant. These factors govern the natural frequency of a system.

Forced Vibration

Forced vibration is where a driving force is continuously applied to make the system vibrate/oscillate. The thing that provides the driving force will be moving at a certain frequency. We call this the driving frequency.

Resonance

If I hold one end of a slinky and let the other oscillate freely we have a free vibration system. If I move my hand up and down I force the slinky to vibrate. The frequency of my hand is the driving frequency.
When the driving frequency is lower than the natural frequency the oscillations have a low amplitude
When the driving frequency is the same as the natural frequency the amplitude increases massively, maybe even exponentially.
When the driving frequency is higher than the natural frequency the amplitude of the oscillations decreases again.

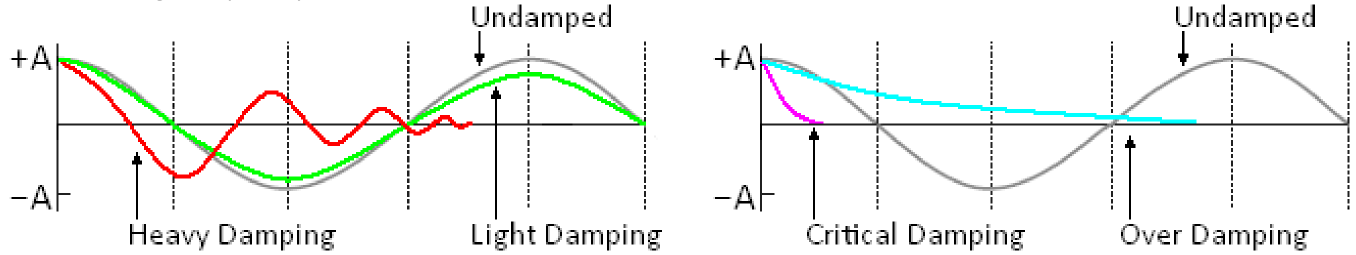


Phase Difference between driver and driven

When the driving force begins to oscillate the driven object the phase difference is 0.
When resonance is achieved the phase difference between them is π.
When the driving frequency increases beyond the natural frequency the phase difference increases to π/2.

Damping

Damping forces oppose the motion of the oscillating body, they slow or stop simple harmonic motion from occurring. *Damping forces act in the opposite direction to the velocity*.
Galileo made an important observation while watching lamps swing in Pisa cathedral. He noticed that the swinging gradually died away but the time taken for each swing stayed roughly the same. The swing of the lamp was being damped by air resistance.



Light damping slowly reduces the amplitude of the oscillations, but keeps the time period almost constant.
Heavy damping allows the body to oscillate but brings it quickly to rest.
Critical damping brings the body back to the equilibrium point very quickly with out oscillation.
Over damping also prevent oscillation but makes the body take a longer time to reach equilibrium.

Damping and Resonance

Damping reduces the size of the oscillations at resonance. There is still a maximum amplitude reached but it is much lower than when the system is undamped. We say that damping reduces the sharpness of resonance. This becomes clearer if we look at the graph on the right. It shows the amplitude of oscillation against frequency for different levels of damping.