

ENG1004 Eng Physics 1

AY2023/24 Trimester 1

Week9: Oscillations (Part 2)

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Content

1. Types of oscillation

2. Simple Harmonic Motion (SHM)

3. Variation with time: x, v, a vs t .
Two types:
(1) Starts at $x = 0$ at $t = 0$ $x = x_0 \sin \omega t$
(2) Starts at $x = x_0$ or $x = -x_0$ at $t = 0$
 $x = x_0 \cos \omega t$ $x = -x_0 \cos \omega t$

4. Variation with displacement: v, a vs x .

- *Energy vs time (KE, PE, TE [Total energy] vs t)*

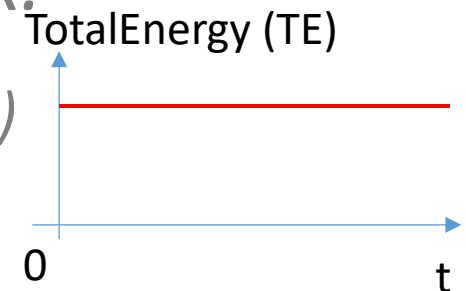
5. Damped Oscillations

6. Forced Oscillations

$$x = x_0 \sin \omega t$$

$$v = \frac{dx}{dt} = x_0 \omega \cos \omega t$$

$$a = -\omega^2 x$$



1. Intro Free, Damped & Forced Oscillations

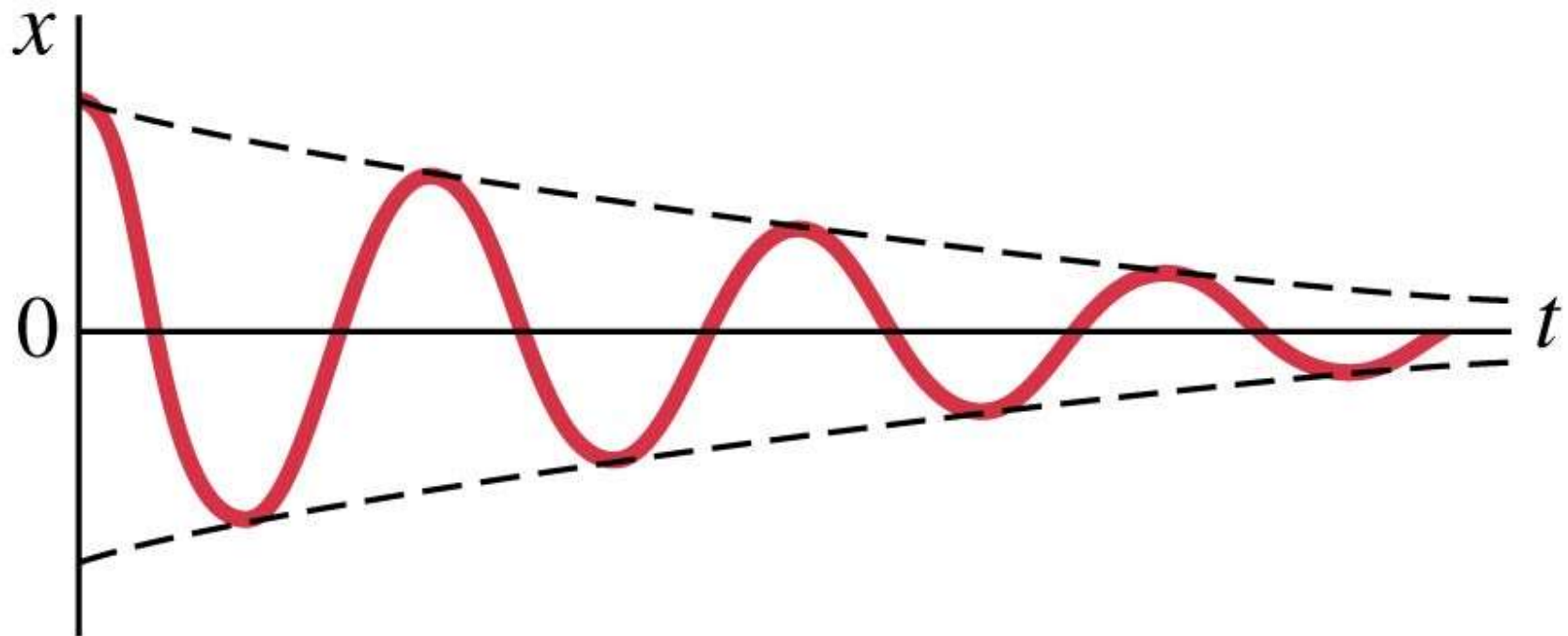
Oscillations will go on forever if undamped.

Damping: Resistive forces acting on oscillation.

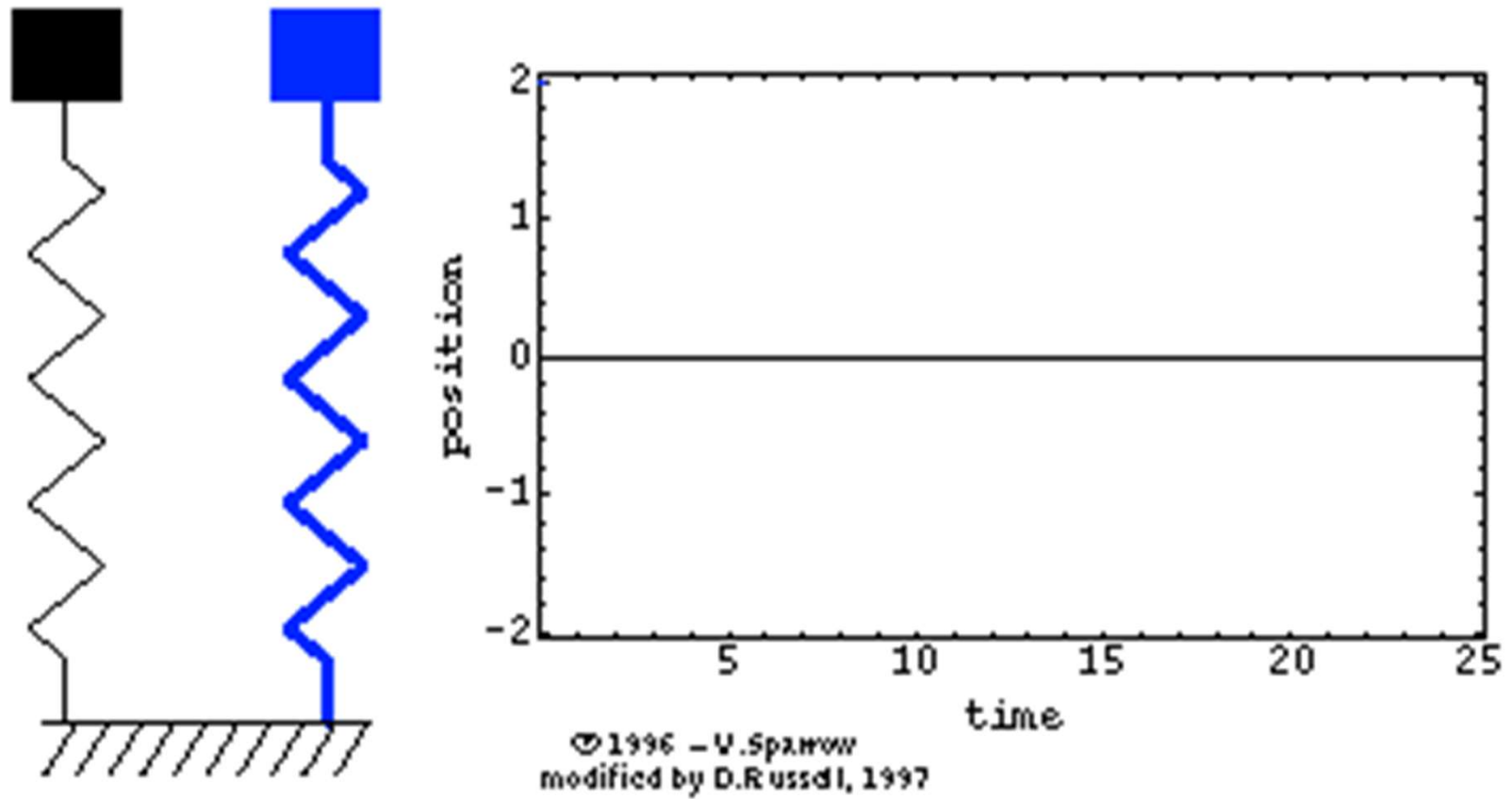
1. Free Oscillations – w/o external stimuli
2. Damped Oscillations - **amplitude** (x_0) of oscillation decreases with time
Cause: Resistive forces from surroundings (eg air resistance).
3. **Forced Oscillations** - Oscillations driven by external oscillatory forces with varying frequencies are known as forced oscillations. (Eg driven by Earthquake)

2. Damped Harmonic Motion

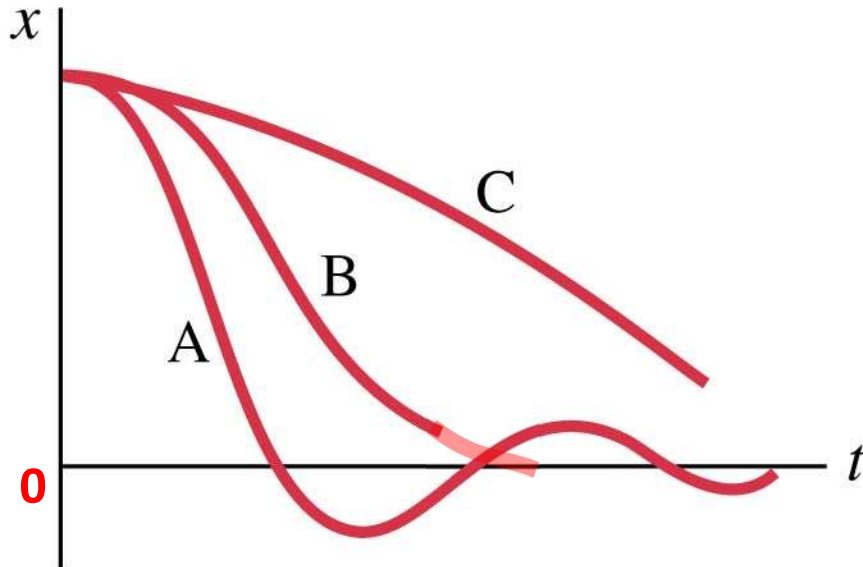
- Damped harmonic motion is harmonic motion with a frictional or drag force.
- If damping is **small**, we can treat it as an “envelope” that modifies un-damped oscillation. (Oscillation with DECREASING amplitudes)



<https://www.acs.psu.edu/drussell/Demos/SHO/damp.html>



2. Damped Harmonic Motion



But, if damping is **large**, it no longer resembles SHM at all.

A: under-damping (light damping): there are a few small oscillations before oscillator comes to rest.

For B & C, **NO Oscillations**

B: critical damping: fastest way to get to equilibrium ($x = 0$).

C: over-damping (heavy damping): system is slowed so much that it takes a **long time (even infinity)** to get to equilibrium ($x = 0$).

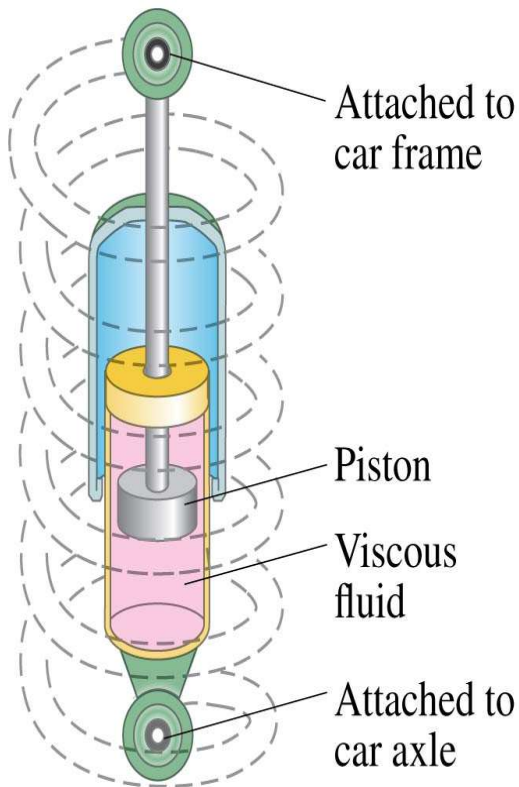
Notice **ONLY Graph A** has oscillation about $x = 0$.

Example: Car/Motorcycle suspensions uses Critical Damping

2. Damped Harmonic Motion

Application of damping

There are systems where damping is unwanted, such as clocks and watches.



automobile shock absorbers



earthquake protection for buildings

Then there are systems in which it is wanted, and often needs to be as close to **critical damping** as possible, such as automobile shock absorbers and earthquake protection for buildings.

Include **weighing scales** and **analog voltmeters/ammeters**.

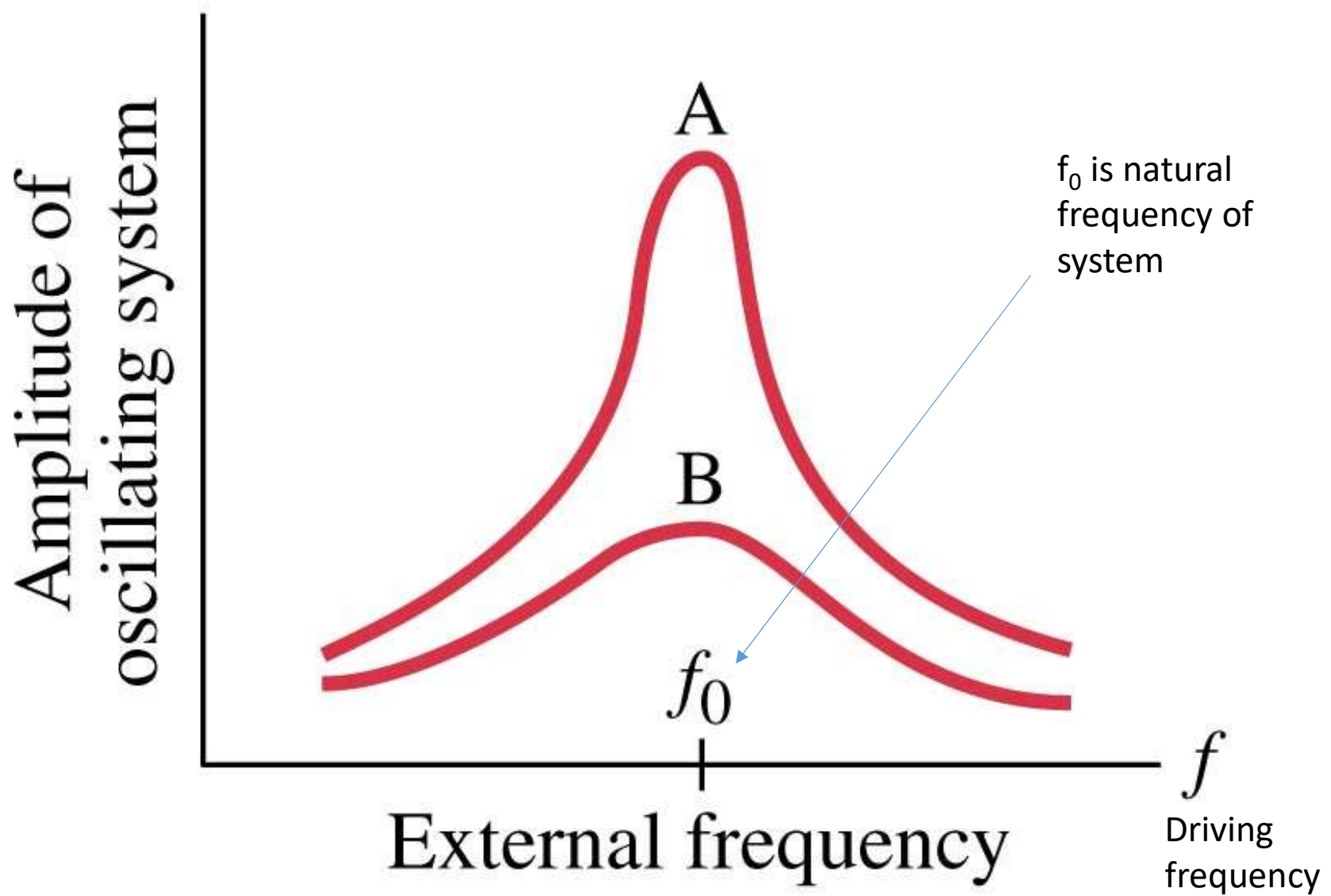


3. Forced Oscillations; Resonance

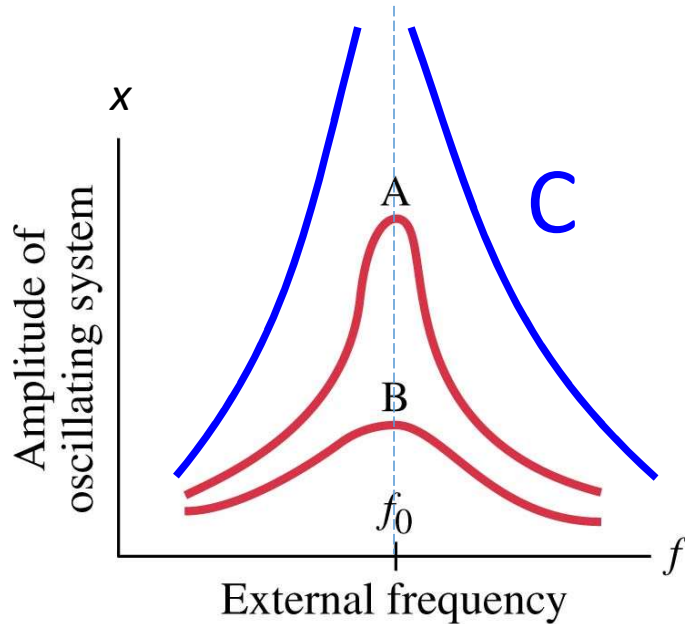
- Occurs when there is a periodic driving force.
Driving force **may or may not have** same period as **natural frequency** of system.
- Resonance: If **driving frequency** same as **natural frequency**, amplitude becomes quite large.

Resonant frequency breaks glass





3. Forced Oscillations; Resonance



A: Small damping

B: Heavy damping

C: No damping

*Critical damping between A and B

C: No damping

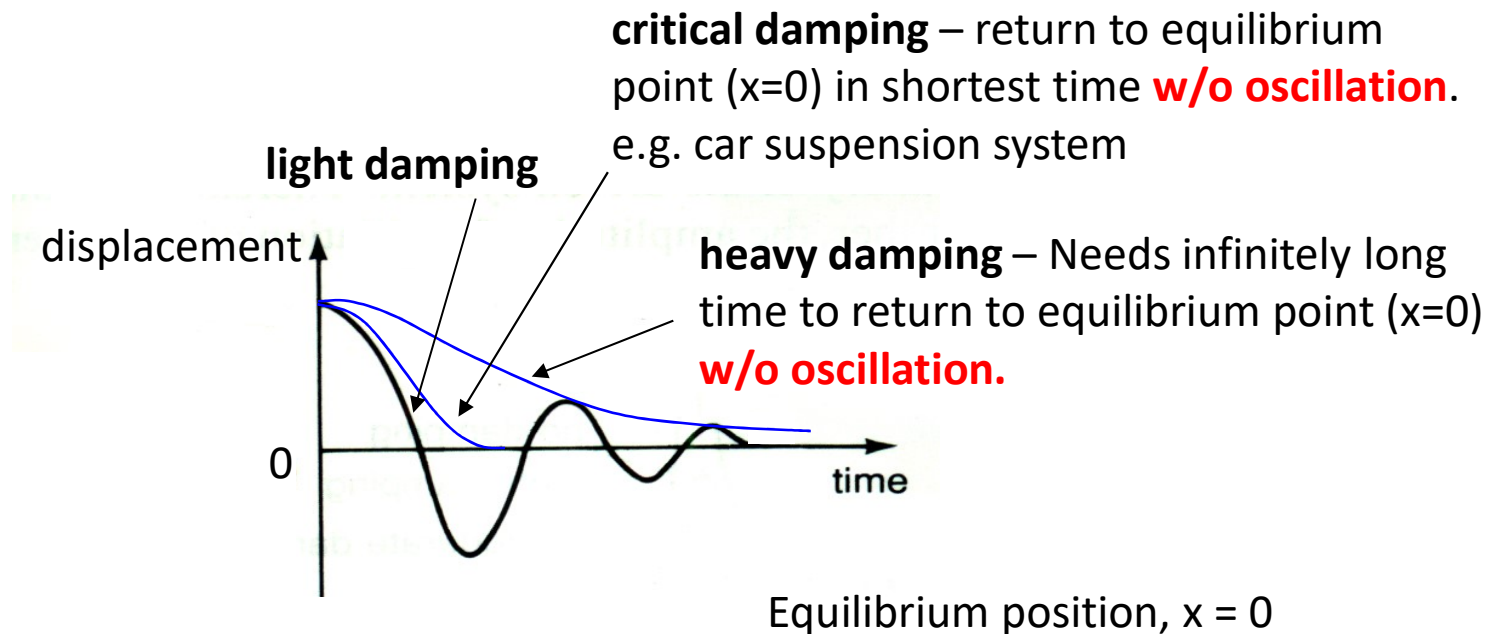
- **Sharpness** of resonant peak depends on the damping.
- If damping is **small** (A), it can be quite sharp; if **damping is larger** (B), it is less sharp.
- Like damping, resonance can be wanted or unwanted. **Musical instruments and TV/radio receivers** depend on it.
- Another application: Microwave Oven.

4. Example

Describe a procedure to measure the spring constant k of a car's springs. Assume that the owner's manual gives the car's mass M and that the shock absorbers are worn out so that the **springs are under-damped**. (See Sections 11–3 and 11–5 of Giancoli.)

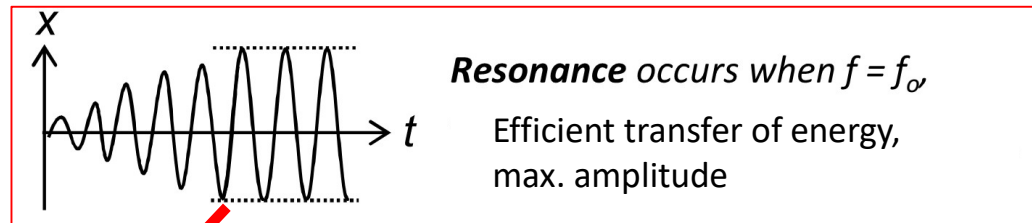
Summary

1. Damping:

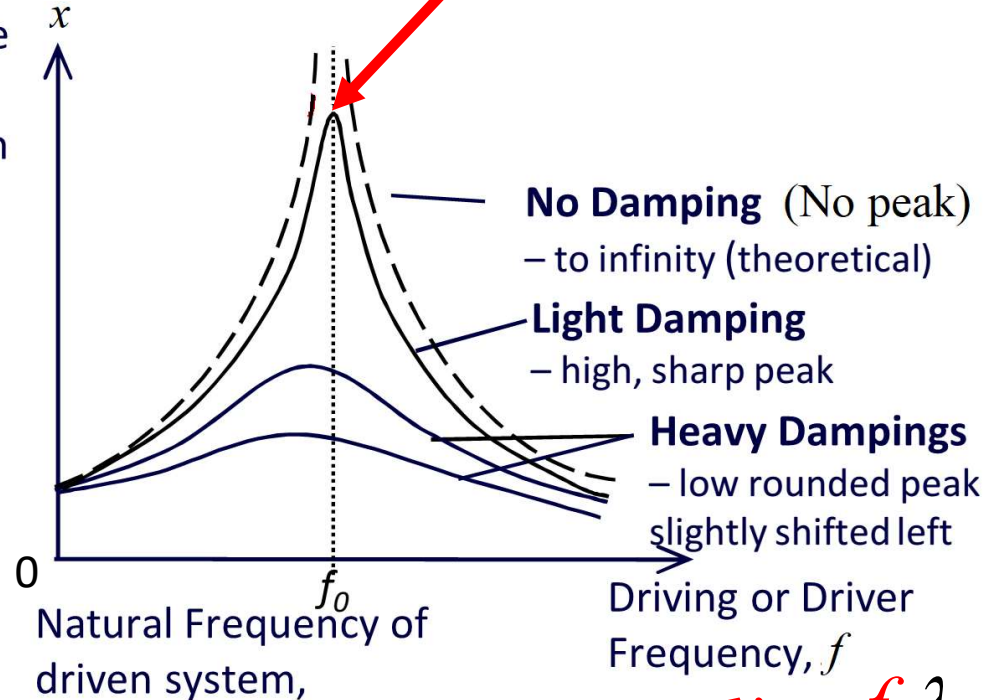


Summary

2. Forced Oscillation:



Amplitude
of Forced
Oscillation



Left

$$v = f\lambda$$

Right

SPRINGS: SERIES VERSUS PARALLEL

Spring constant k : Larger k means harder to extend spring

PARALLEL SPRINGS

- One spring requires F to extend to x .
- Two identical such springs in PARALLEL requires a force LARGER than F to extend to x
- **Means effective spring constant of // springs is HIGHER.**

Parallel springs (4 springs): $k_{\text{effective}} = k_1 + k_2 + k_3 + k_4$

SERIES SPRINGS

- One spring requires F to extend to x .
- Two identical such springs in SERIES requires a force SMALLER than F to extend to x
- **Means effective spring constant of series springs is SMALLER.**

Series springs (4 springs): $\frac{1}{k_{\text{effective}}} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{1}{k_4}$

FORCE: (HOOKE'S LAW): $F = k x$

SPRINGS: SERIES VERSUS PARALLEL

PARALLEL SPRINGS

Parallel springs (4 identical springs): $k_{\text{effective}} = k + k + k + k$

Parallel springs (4 identical springs): $k_{\text{effective}} = 4k$

