DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS
IB PHYSICS

OPTION B-4
FORCED VIBRATIONS AND RESONANCE

Essential Idea:

- In the real world, damping occurs in oscillators and has implications that need to be considered.

Nature Of Science:

- Risk assessment:
  - The ideas of resonance and forced oscillation have application in many areas of engineering ranging from electrical oscillation to the safe design of civil structures.
  - In large-scale civil structures, modeling all possible effects is essential before construction.

International-Mindedness:

- Communication through radio and television signals is based on resonance of the broadcast signals

Understandings:

- Natural frequency of vibration
- Q factor and damping
- Periodic stimulus and the driving frequency
- Resonance

Applications And Skills:

- Qualitatively and quantitatively describing examples of under-, over- and critically-damped oscillations
- Graphically describing the variation of the amplitude of vibration with driving frequency of an object close to its natural frequency of vibration

Applications And Skills:

- Describing the phase relationship between driving frequency and forced oscillations
- Solving problems involving Q factor
- Describing the useful and destructive effects of resonance

Guidance:

- Only amplitude resonance is required

Data Booklet Reference:

$$Q = 2\pi \frac{energy - stored}{energy - dissipated - per - cycle}$$

$$Q = 2\pi * resonant - frequency * \frac{energy - stored}{power - loss}$$

$$Q = 2\pi \frac{energy\ stored}{energy\ dissipated\ per\ cycle}$$

$$Q = 2\pi\ x\ resonant\ frequency\ x\ \frac{energy\ stored}{power\ loss}$$

Utilization:

- Science and technology meet head-on when the real behaviour of damped oscillating systems is modelled

Aims:

- Aim 6: experiments could include (but are not limited to): observation of sand on a vibrating surface of varying frequencies; investigation of the effect of increasing damping on an oscillating system, such as a tuning fork; observing the use of a driving frequency on forced oscillations

Aims:

- Aim 7: to investigate the use of resonance in electrical circuits, atoms/molecules, or with radio/television communications is best achieved through software modelling examples

Oscillation vs. Simple Harmonic Motion

- An <u>oscillation</u> is any motion in which the displacement of a particle from a fixed point keeps changing direction and there is a periodicity in the motion i.e. the motion repeats in some way.
- In <u>simple harmonic motion</u>, the displacement from an equilibrium position and the force/acceleration are proportional and opposite to each other.

Energy in SHM

$$E = PE + KE = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$$

$$E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2 = cons\tan t$$

$$\frac{1}{2}kx^2 + \frac{1}{2}mv^2 = \frac{1}{2}kA^2$$

$$v = \pm\omega\sqrt{A^2 - x^2}$$

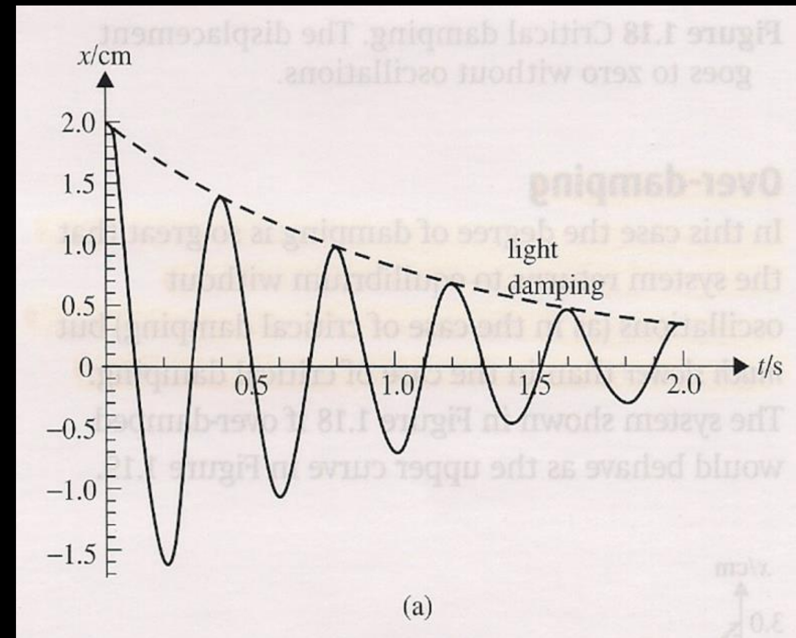
$$v_{\max} = \omega A$$

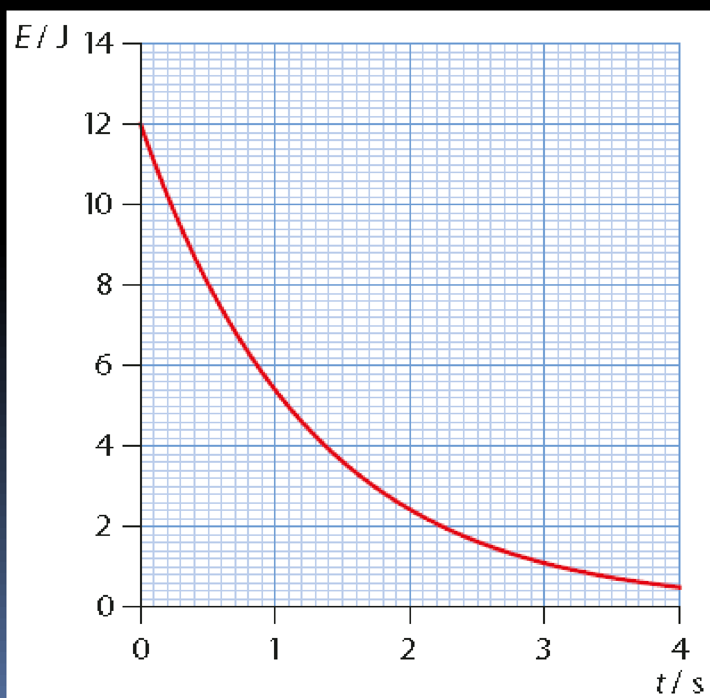
Damping

- In the ideal world, SHM can go on forever without energy loss
- In the real world, energy is lost and the motion eventually stops
- The rate at which energy is lost is called damping

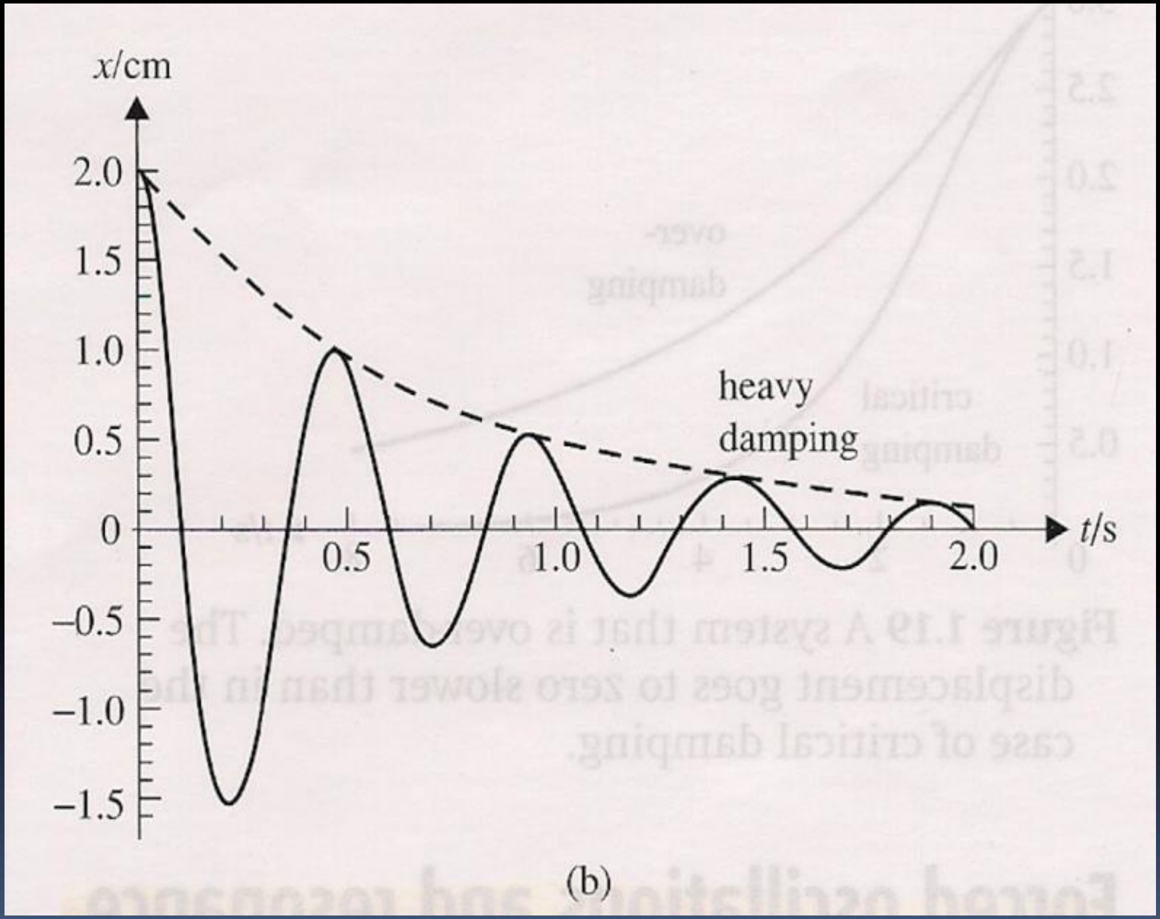
Light Damping or Underdamped

- Oscillations decrease slowly with time
- Energy loss is exponential with all damping

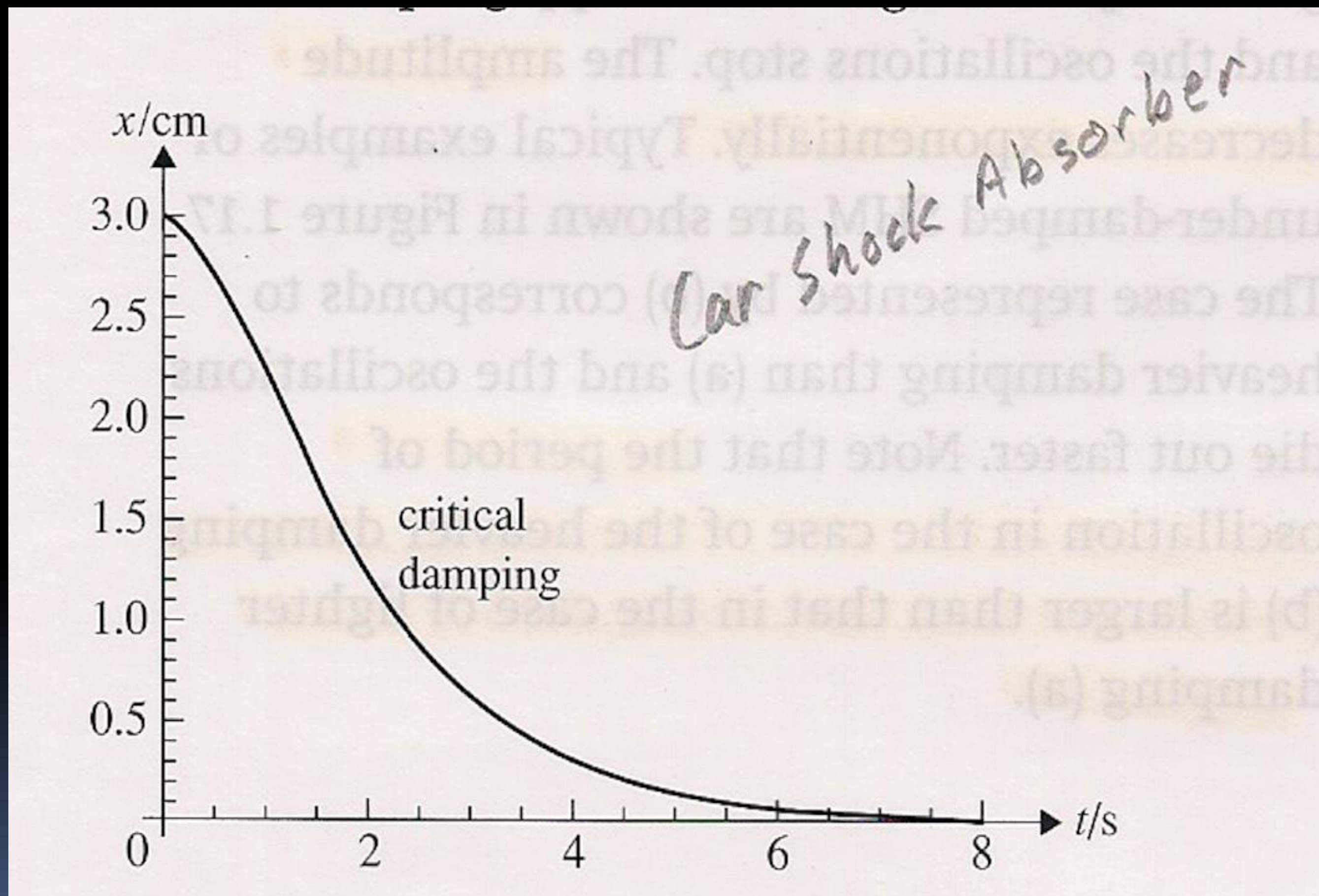




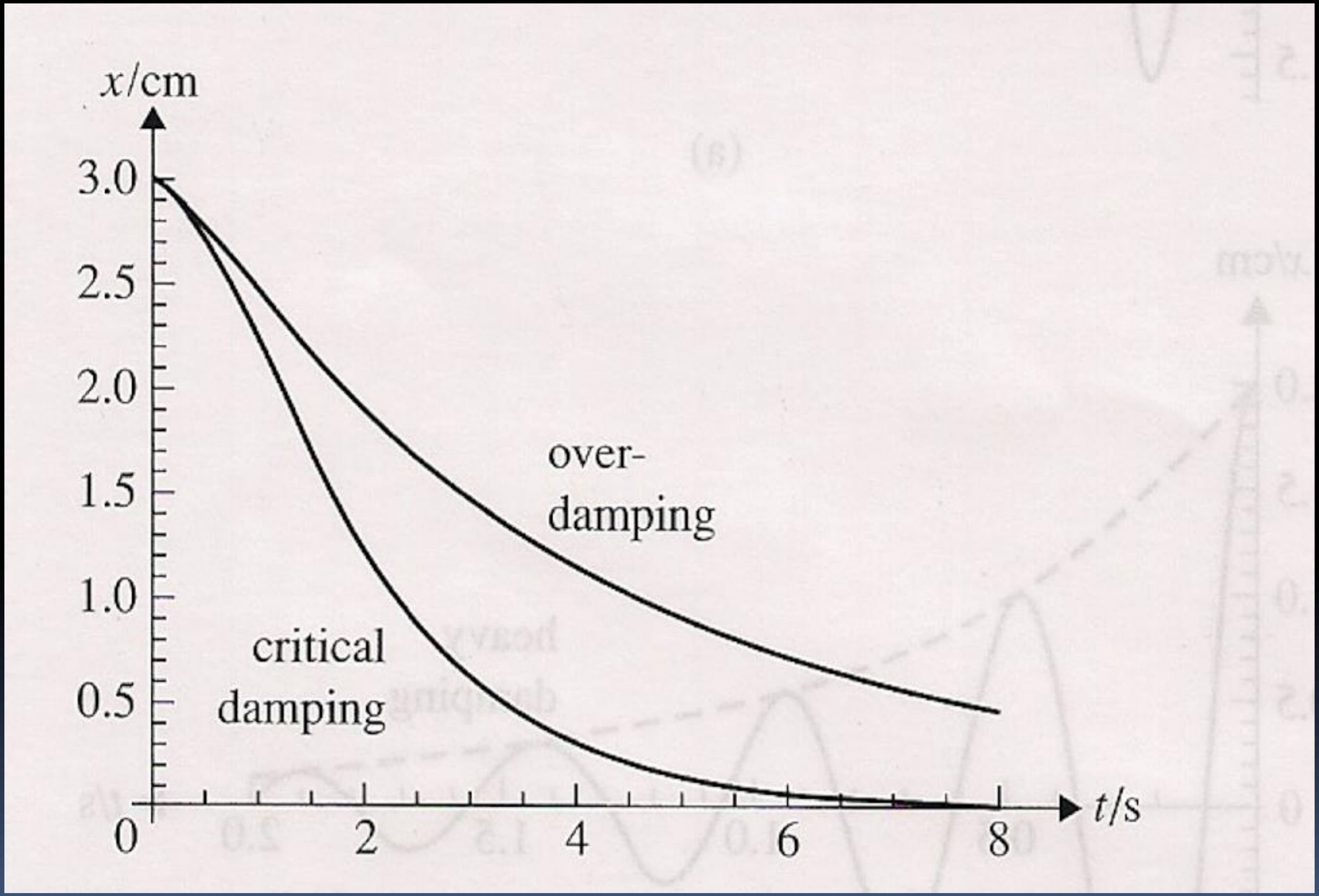
Heavy Damping or Overdamped



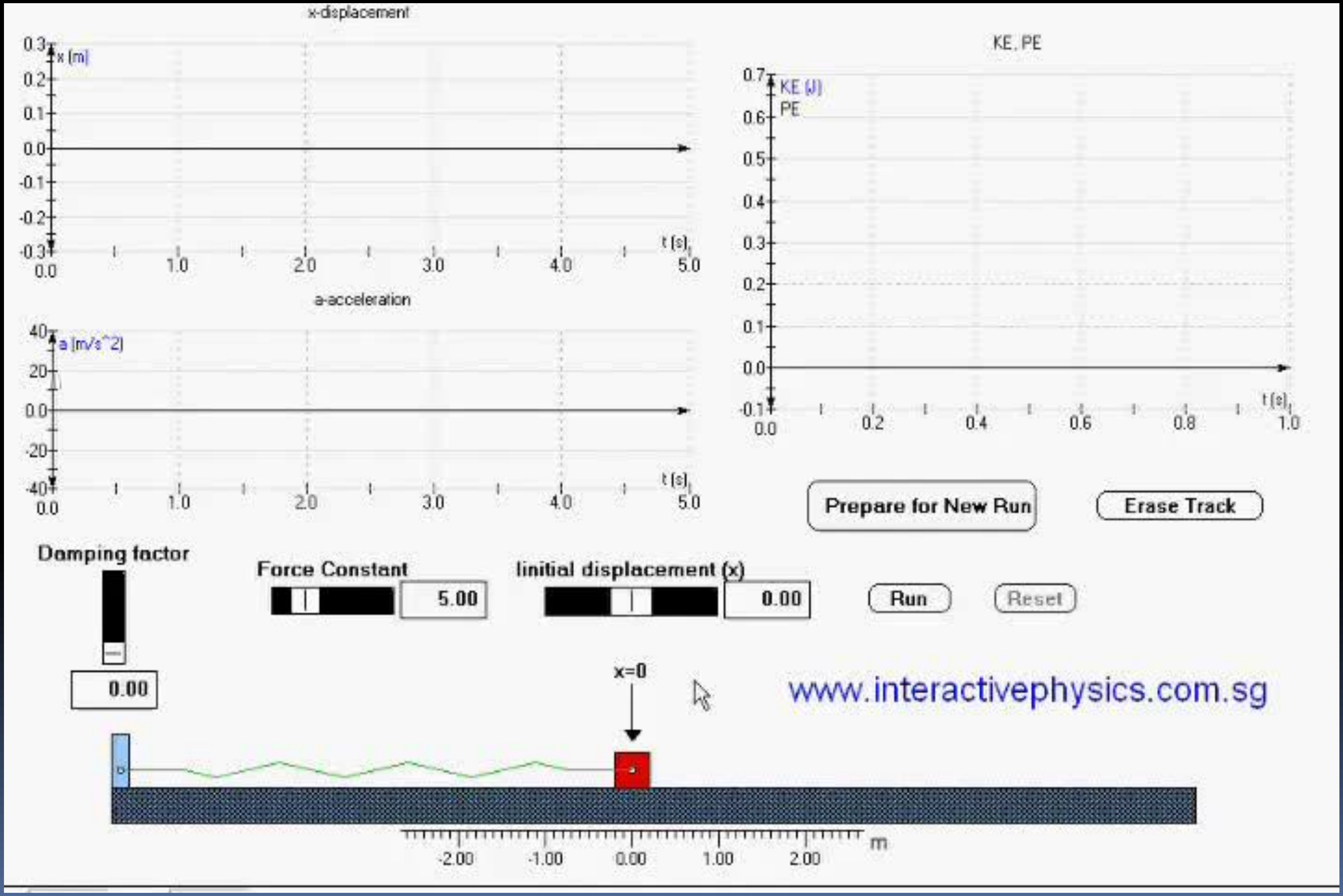
Critical Damping



Over-Damping



Damping


x-displacement
x (m)
t (s)
a-acceleration
a (m/s^2)
t (s)
KE, PE
KE (J)
PE
t (s)
Prepare for New Run
Erase Track
Damping factor
0.00
Force Constant
5.00
Iinitial displacement (x)
0.00
Run
Reset
x=0
www.interactivephysics.com.sg
m

Q-Factor

- Describes how quickly an underdamped system will die out
- Can be expressed in terms of energy and/or power

$$Q = 2\pi \frac{E_{stored}}{E_{dissipated}}$$

$$Q = 2\pi \frac{E_{stored}}{PT}$$

$$Q = 2\pi \frac{1}{T} \frac{E_{stored}}{P}$$

$$Q = 2\pi f_0 \frac{E_{stored}}{P}$$

$$Q = 2\pi \frac{energy\ stored}{energy\ dissipated\ per\ cycle}$$

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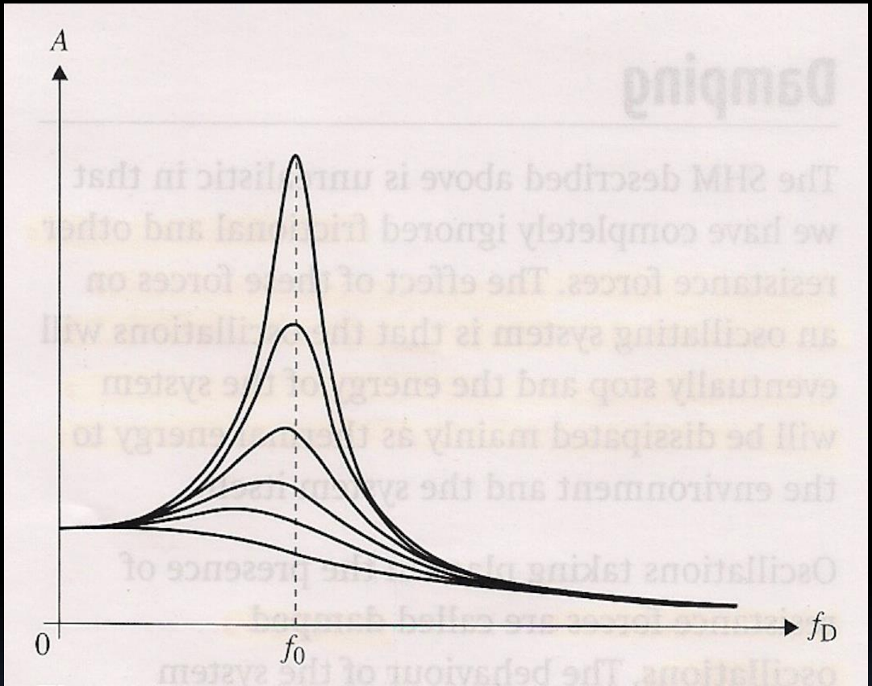
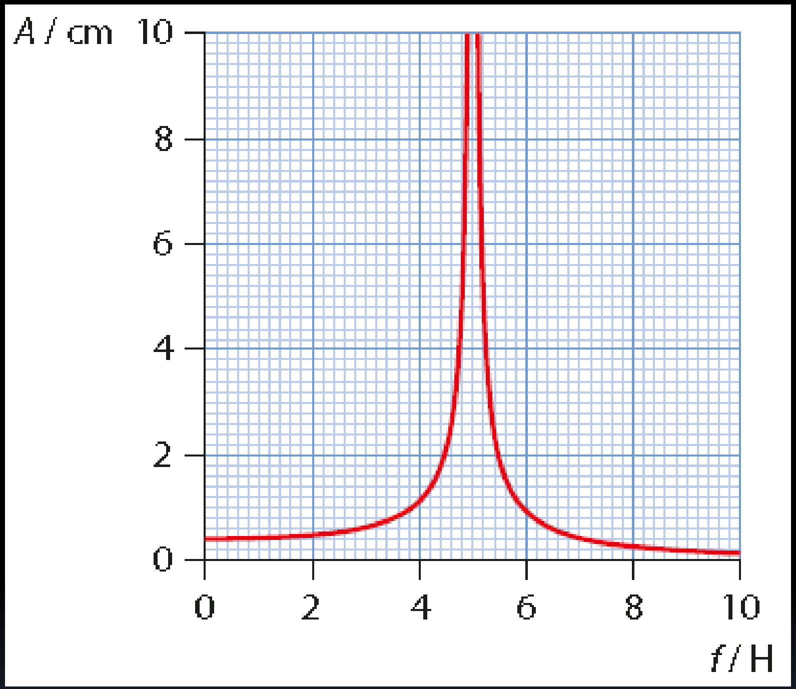
Forced Oscillations

- We can apply a force to overcome damping and maintain a constant amplitude (grandfather clock)
- Or, we can apply a force to increase amplitude
- However, the frequency of the applied force (***driving force***), f_D must be close to or the same as the ***natural frequency***, f_o

Forced Oscillations



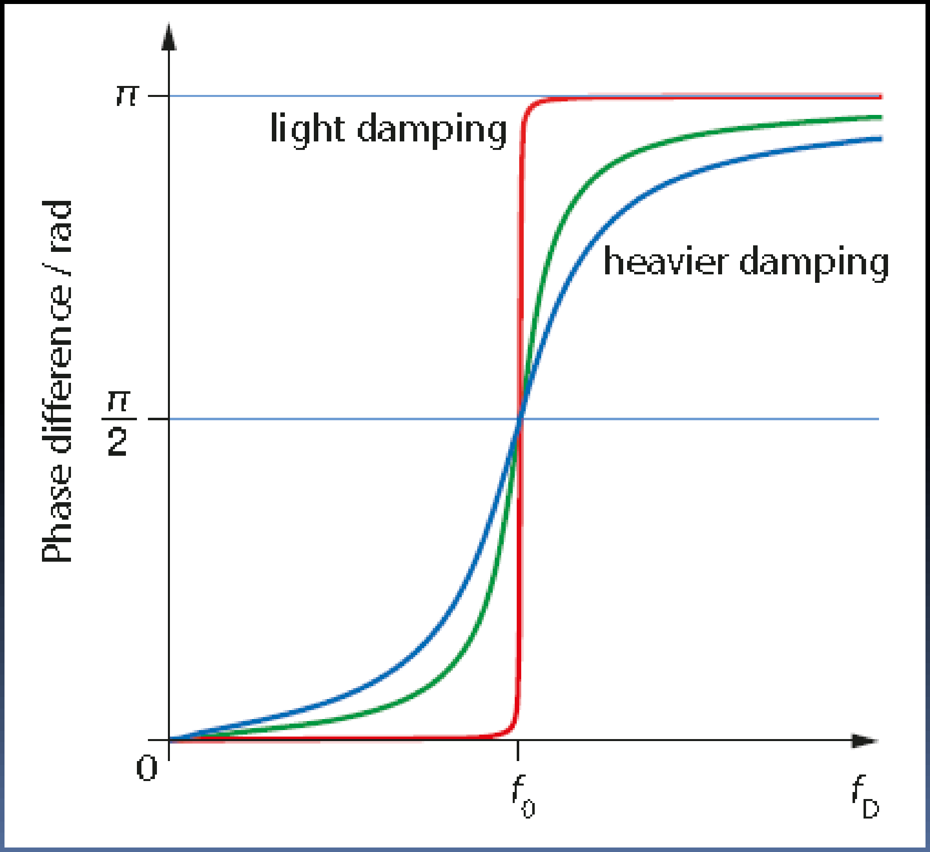


With Damping

Without Damping

Phase Difference

- Phase difference between the displacement of the system and the displacement of the driver



Forced Oscillations

Resonance

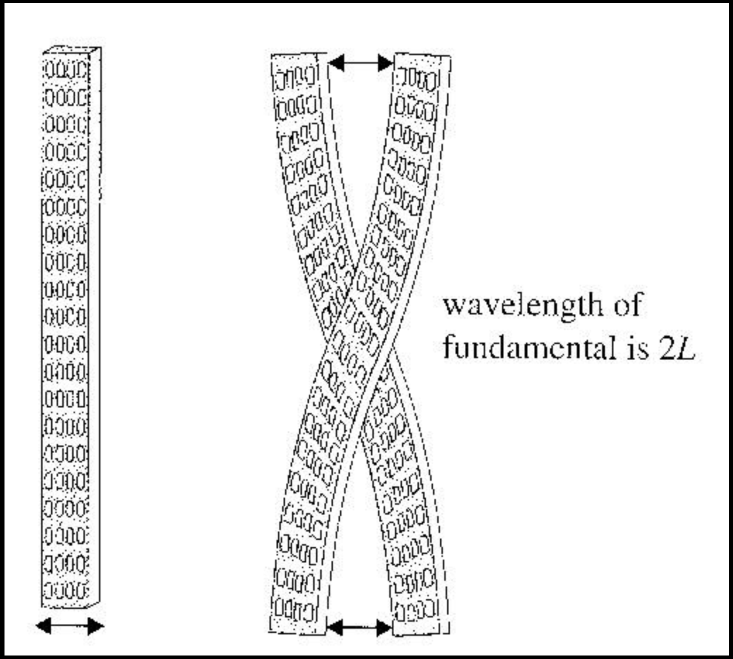
- The state in which the frequency of the externally applied periodic force equals the natural frequency of the system is called resonance. This results in oscillations with large amplitude.

Resonance

- Resonance occurs whenever a system that is capable of oscillation or vibration is subjected to an external disturbance with a frequency equal to the natural frequency of the system itself
  - In that case, the amplitude of the oscillations will increase
  - If the frequencies don’t match, the amplitude is smaller or cyclical

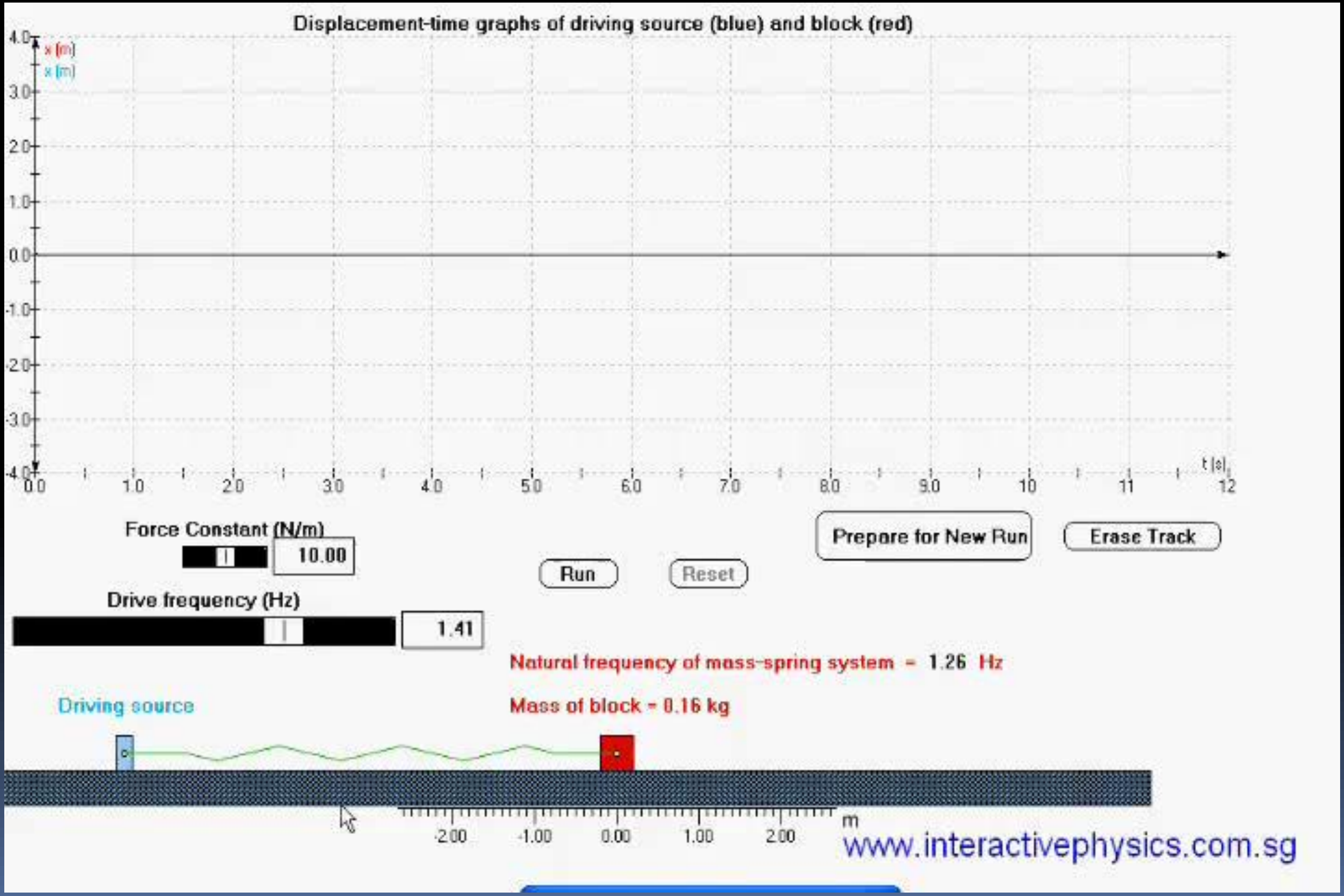
Resonance

- Examples of resonance
  - Unbalanced tire
  - Ceiling fan
  - Rubbing a finger over the top of a glass
  - Buildings in earthquakes
    - Height of the building determines its natural frequency



Fun With PhET

Resonance and Forced Oksilations



Resonance

Resonance

Effects of Resonance on Buildings

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Tacoma Narrows Bridge Collapse

Homework

#58-64

Beautiful Resonance