PHY 1106: Waves and Oscillations

UNIVERSITY of EXETER

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THIN FILM PHOTONICS

UNIVERSITY of EXETER

Module Texts:

Young H.D. and Freedman R.A.
University Physics (Addison-Wesley)

Supplementary Reading:

Pain H.J.,
The Physics of Vibrations and Waves (Wiley)

I. The Physics of *SHM*.

Simple Harmonic Motion - motion which is periodic, repeating, oscillatory …etc. (...loose definition.)

[rigorous definition to follow after first analysis]

There will be three analyses for periodic motion.

i) SHM with no damping (frictionless system).

ii) SHM with damping (friction in the system).

iii) Forced oscillation. (system is driven by an external force)

1.1 Simple (undamped) harmonic motion.

In 1D, a particle displaced from an equilibrium position, eg. a spring on a horizontal surface.

Hooke's Law;

Restoring force exerted by the spring

Force used to stretch spring

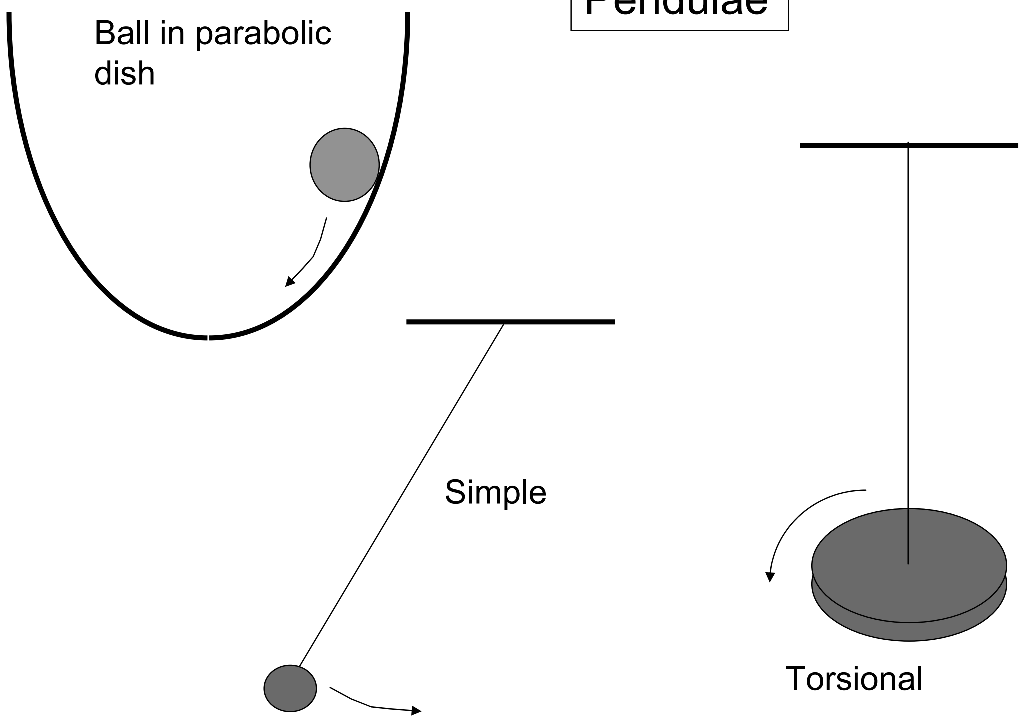
Spring constant

Displacement of the object

-ve sign as x increases, the force increases in the opposite direction

…other examples of SHM

Pendulae



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PHY 1106: Waves and Oscillators (Lecture 1)

SHM analysis (undamped)

We do this by ………………………….. and setting up the equation of motion.

1) Any net force on an object of mass **m** will produce an …………………. **a**

2) The ……………………. **F** of the system, causes the object of mass **m** to accelerate

Combining 1)and 2);

And re-writing;

rearranging;

[This is the equation of motion]

This provides a definition for SHM;

- The ………………. of an object in SHM is proportional to its ………………. from equilibrium,
- and is in the opposite direction to the …………………

Check on dimensions;

Since this is an equation that balances forces, each side has the units of Newtons.

…the dimensions of the term; $\frac{k}{m}$ are of interest.

$$\left[\frac{\mathrm{k}}{\mathrm{m}}\right] = \left[\frac{\ddot{\mathrm{x}}}{\mathrm{x}}\right] \xrightarrow{\text{dimensions}}$$

i.e., the dimensions of $\left[\frac{k}{m}\right]$ are;.

therefore; $\sqrt{\frac{k}{m}}$ has the dimensions of.

where f is frequency,
and c is a constant

For periodic motion, however, remember the following relations;

Period

Frequency

Angular frequency

Frequency

NB: T is time for one cycle of motion (in seconds)

f is frequency of oscillation (in Hertz)

ω is the angular frequency (rads per second)

Solution to the equation of SHM.

We solve the equation that predicts the variation of displacement **x** with time **t**, using the following;

$$x = A\cos\omega t \quad 1)$$

Differentiate once to get velocity 2)

Differentiate a second time to get acceleration. 3)

by substitution of 1) into 3); 4)

From the previous pages, however, we have three relations involving ω, **f, k** and **m.**

$$\ddot{x} = -\frac{k}{m}x$$

$$\omega = 2\pi f$$

Tie these equations together with equation 4) and we get a solution for the …………………………………………. ……………………………………………………………

This is the **<u>resonant</u>** frequency of the spring / mass system; i.e. when it is set oscillating, it will automatically oscillate with this frequency f.

Note;

- It only depends on **…………………..**
- It does not depend on the ………… of the oscillation.

The natural frequency of a <u>simple pendulum</u>;

The natural frequency of a <u>torsional pendulum</u>;

(Torsional const.)

(Moment of Inertia)

The natural frequency of <u>human walking</u>

Young: chap.13

Question.

A spring with mass 400g, is stretched by 75cm. If it is then set oscillating, at what frequency does it resonate?

Answer.

First find the spring constant using Hooke's Law.

Then use the frequency equation for SHM,