PH4

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1 Simple Harmonic Motion

In simple harmonic motion, acceleration is proportional to displacement and opposite in sign;

$$x = x_m \cos(\omega t + \phi)$$
$$\frac{\partial x}{\partial t} = -\omega x_m \sin(\omega t + \phi)$$
$$\frac{\partial^2 x}{\partial t^2} = -\omega^2 x_m \cos(\omega t + \phi)$$

An example of simple harmonic motion is a mass on a spring.

$$T = 2\pi\sqrt{\frac{m}{k}}$$

- m is mass
- k is spring constant

Pendula aren't but if they are long and the angle is small they pretty much are.

$$T = 2\pi\sqrt{\frac{L}{g}}$$

- L is length

1.1 Uniform Circular Motion

The projection of a point moving in uniform circular motion on a diameter of the circle in which the motion occurs executes SHM.

1.2 Relationships between Velocity, Acceleration & Displacement

1.3 Damped Oscillations

The energy of an oscillating system is the only factor directly related to the amplitude of the oscillation. If energy is removed from the system over time, such as by friction, the amplitude of the oscillation decreases over time. This is called **damped harmonic motion**. In damped harmonic motion, frequency and period stay the same, as they are not related to amplitude. In most cases, the damping is caused by an external force which does work in the opposite direction to velocity. Damped systems obey the following;

$$x(t) = x_m e^{-\frac{bt}{2m}} \cos\left(t\sqrt{\left(1 - \frac{b}{2m}\right)^2} + \phi\right)$$

1.4 Driven Oscillations

If energy is put into an oscillating system over time, the system is undergoing **driven oscillation**. Every system has a **natural frequecy** ω_d at which it oscillates if the oscillation is driven at this natural frequency, the driving **resonates** with the oscillation, and things get a bit out of hand.

$$x_m = \frac{F_0}{\sqrt{m^2\left(\omega^2 - \omega_d^2\right)^2 + b^2\omega_d^2}}$$

2 Electromagnetism

$$F = \frac{q_1 q_2}{4\pi\epsilon_0}$$

2.1 Fields

A field is a load of numbers. Vector fields are the best fields, and all the rest suck, so we only care about vector fields. A uniform field is a field where all the vectors are parallel. In a uniform electric field there is half the potential difference halfway between the poles, that is to say

$$E = V/d$$

when working with diagrams describing a magnetic field. Current traveling into the the page is expressed by a small circle with a cross inside it. Current traveling out of the page can be shown by a small circle witha dot in its centre.

The "right hand rule", holding one's hand in a "thumbs up" position, can tell the the dirction of a rotating magnetic field (one's fingers) around a wire carrying a cur rent in a certain direction (your thumb).
The "left hand rule", holding a thumbs up position then pointing the index finger and pointing the middle finger perpendicular to the palm, tells you the direction of the direction of movement of a wire (thumb) with a magnetic field (index finger) and current (middle finger)

The magnitude of an electric field can be defined as the ratio of force to the relevant property. In this case, current and length of conductor. The angle of the wire in the field also affects the force, and hence can be described thus:

$$F = BIL\sin(\theta)$$

Unit of B: $NA^{-1}m^{-1}$ or tesla T

2.2 Capacitors

Capacitors are a way to store energy/charge. The energy is stored in the electric field inbetween the two plates.

$$C = \frac{Q}{V} = \frac{\epsilon A}{d}$$

$$W = \frac{1}{2}QV = \frac{1}{2}CV^2$$

- C is capacitance
- Q is charge
- V is potential difference
- ϵ is the permiativity of free space
- A is the area of the plates
- d is the distance between the plates
- W is the energy stored in the field between the plates

For capacitors in parallel;

$$C = \sum_{i=1}^{n} c_i$$

For capacitors in series;

$$\frac{1}{C} = \sum_{i=1}^{n} \frac{1}{c_i}$$

Regarding discharging capacitors,

$$V = V_0 e^{-\frac{t}{RC}}$$
$$Q = Q_0 e^{-\frac{t}{RC}}$$
$$I = I_0 e^{-\frac{t}{RC}}$$