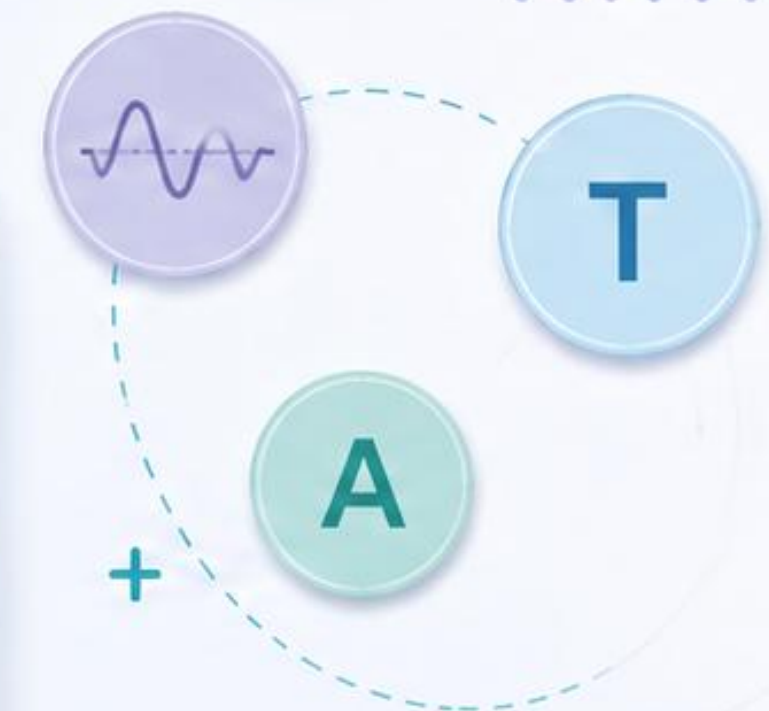
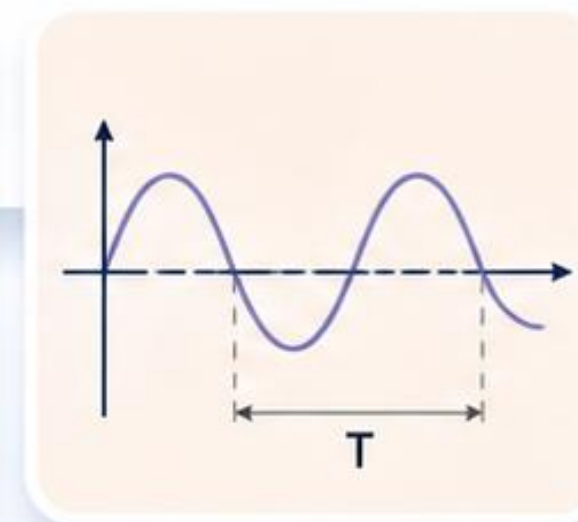
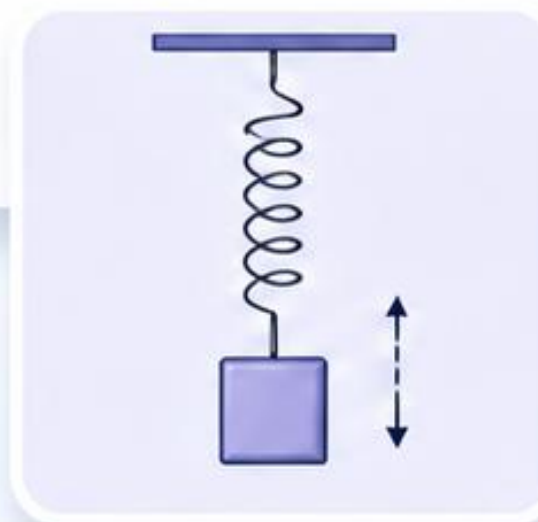
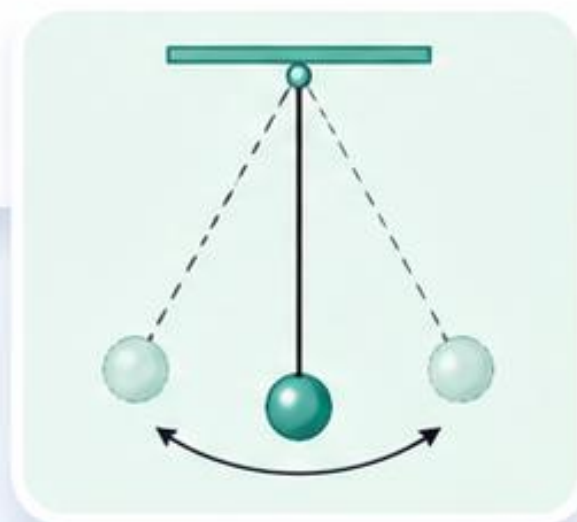


Chapter 13

Oscillations

SHM • Period • Amplitude

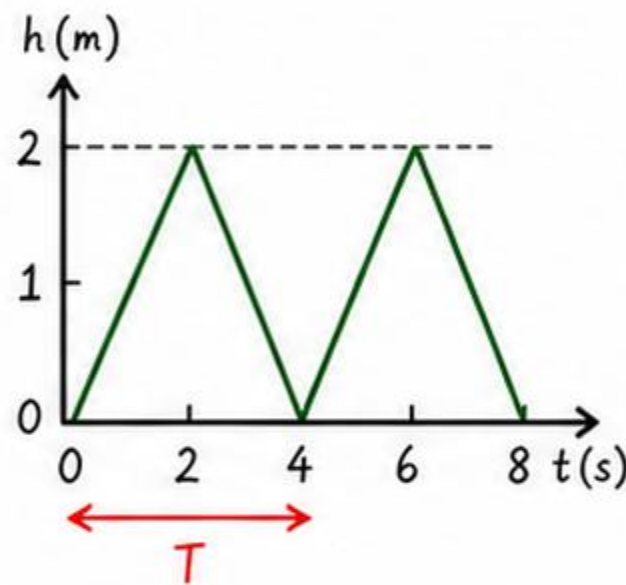


PERIODIC & OSCILLATORY MOTION

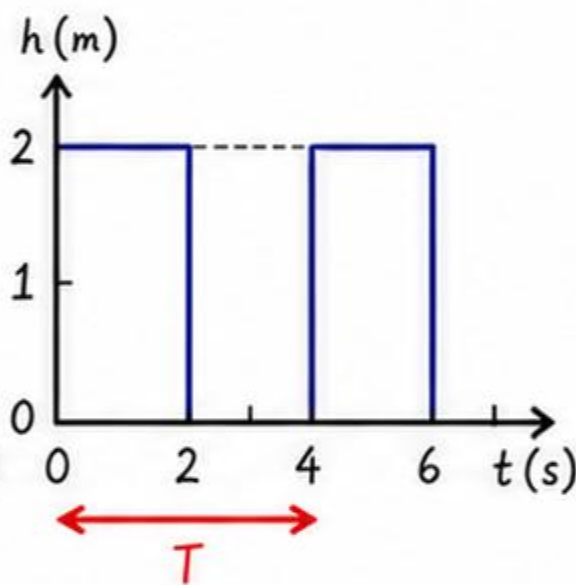
PERIODIC MOTION

motion that repeats itself after equal intervals of time.

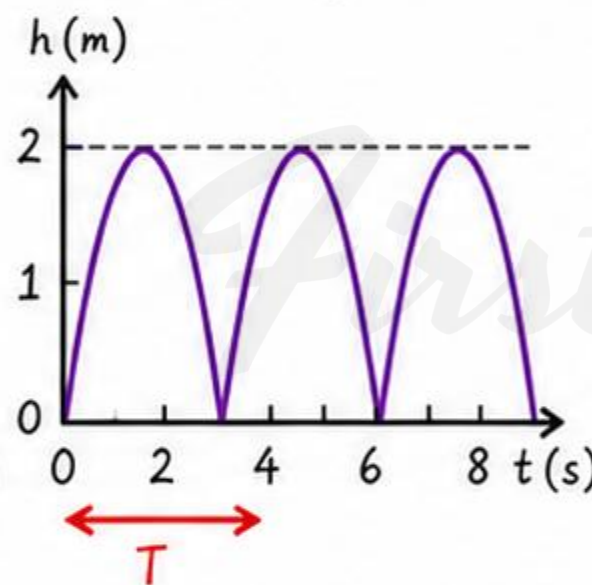
① Insect on a ramp



② Child on a step



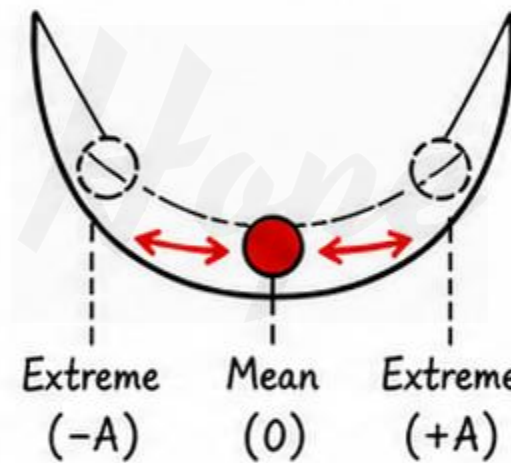
③ Bouncing ball



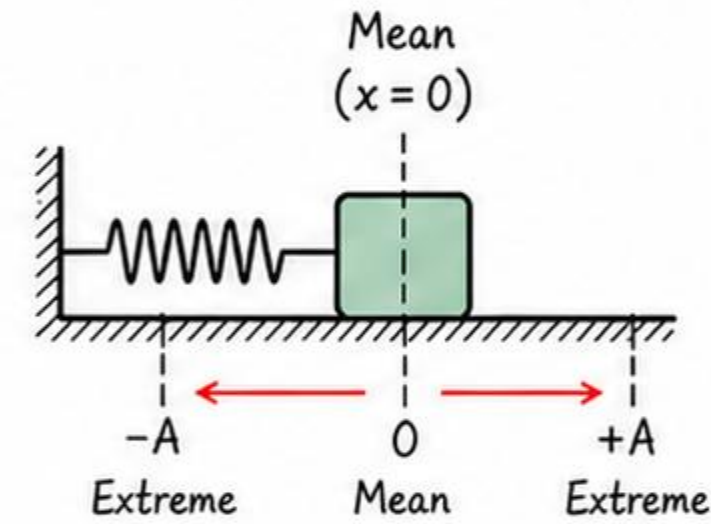
OSCILLATORY MOTION

repeated to-and-fro motion about a stable equilibrium position.

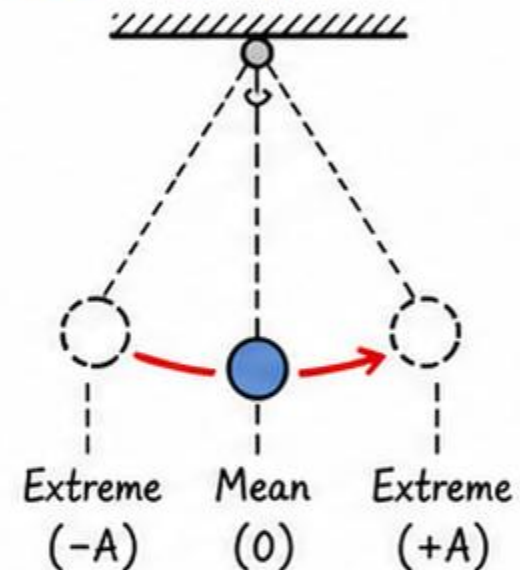
① Ball in a bowl



② Spring-block system

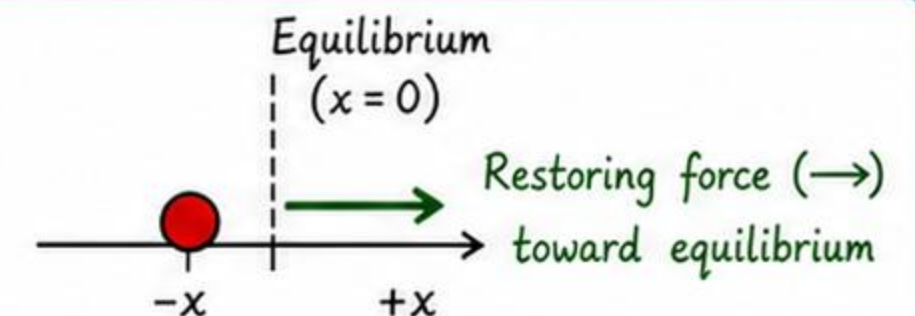


③ Simple pendulum



- Every **oscillatory** motion is **periodic**, but every periodic motion need not be oscillatory.
- Uniform circular motion is **periodic** but **not oscillatory**.

- “oscillation” often describes lower frequency and “vibration” higher frequency; there is no basic physical difference.
- A restoring force acts toward the equilibrium position when the system is slightly displaced.



PERIOD, FREQUENCY & ANGULAR FREQUENCY

① PERIOD (T)

- The least time after which the motion repeats itself.
- SI unit: second (s).

T = time for one complete oscillation

② FREQUENCY (ν)

- The number of oscillations (cycles) per unit time.

$$\nu = \frac{1}{T}$$

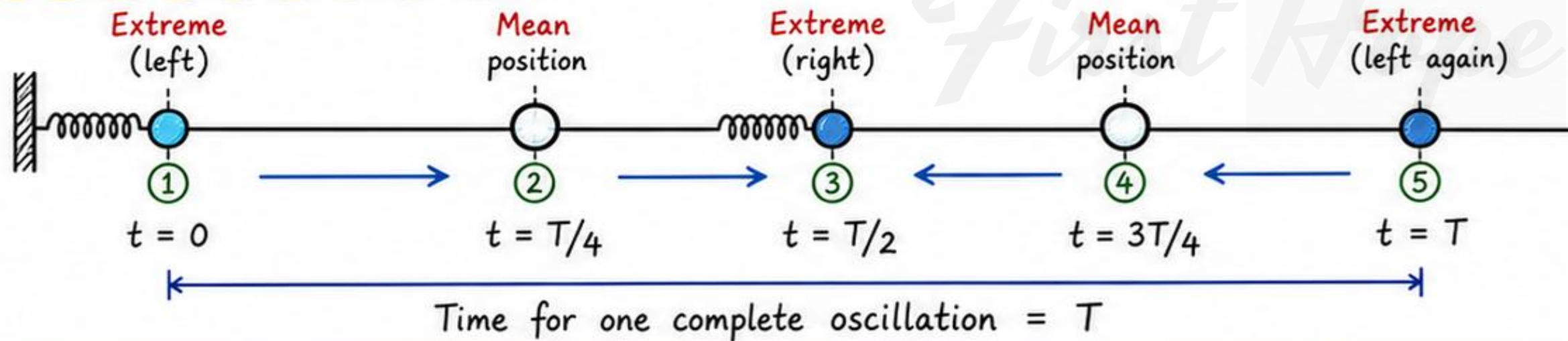
- SI unit: hertz (Hz), $1 \text{ Hz} = 1 \text{ s}^{-1}$.

③ ANGULAR FREQUENCY (ω)

$$\omega = 2\pi\nu = \frac{2\pi}{T}$$

- SI unit: radian per second (rad s^{-1}).

ONE COMPLETE OSCILLATION



KEY:

① → ② → ③ → ④ → ⑤ : one complete cycle
Time taken = T

EXAMPLE - HEARTBEAT

A person's heart beats 75 times per minute.
Find the frequency (ν) and the time period (T) of a heartbeat.

Given: 75 beats per minute
= 75 beats in 60 s

Frequency, $\nu = \frac{75}{60} = 1.25 \text{ Hz}$ $\nu = 1.25 \text{ Hz}$

Time period, $T = \frac{1}{\nu} = \frac{1}{1.25} = 0.80 \text{ s}$ $T = 0.80 \text{ s}$

EXAMPLES OF TIME SCALES



Quartz crystal oscillator:
time scale $\sim 10^{-6} \text{ s}$ (microseconds)



Planet Mercury:
orbital period ~ 88 days



Halley's comet:
period ~ 76 years

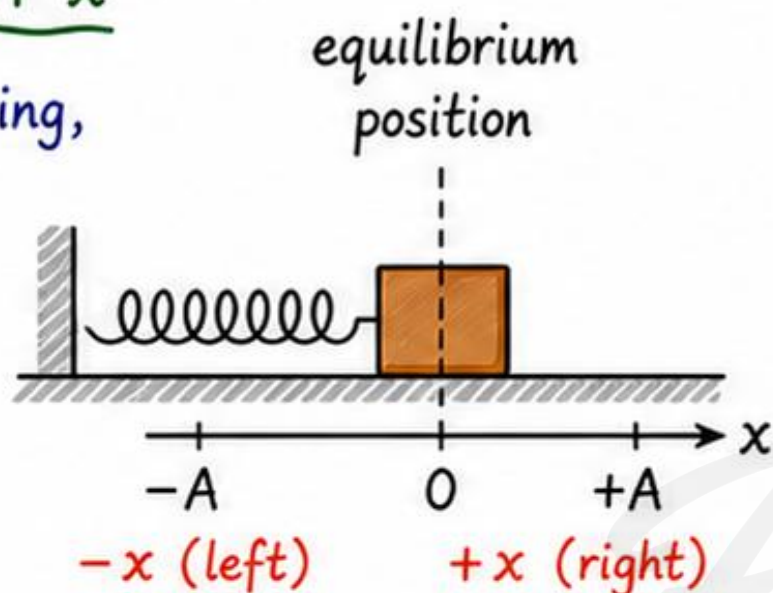
DISPLACEMENT IN OSCILLATIONS

displacement here is the time-varying physical quantity used to describe an oscillation, not only change of position.

① LINEAR DISPLACEMENT x

of a block attached to a spring, measured from equilibrium.

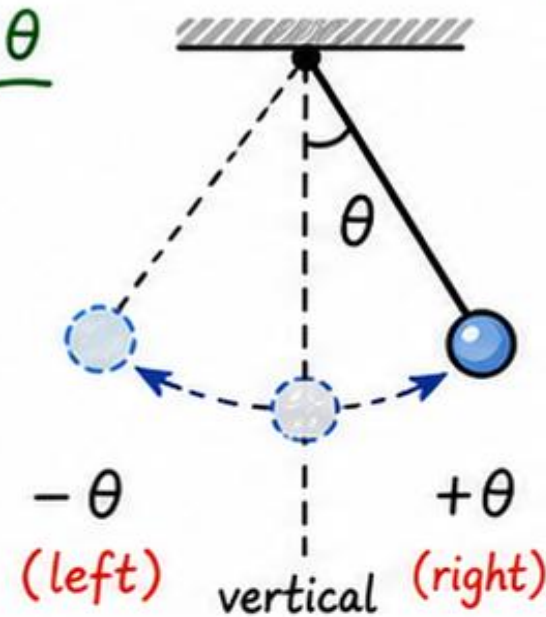
Negative to the left,
positive to the right.



② ANGULAR DISPLACEMENT θ

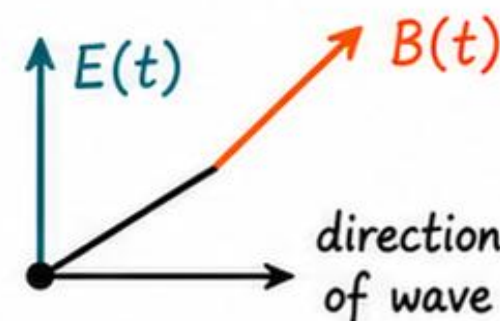
of a simple pendulum, measured from vertical.

Negative to the left,
positive to the right.



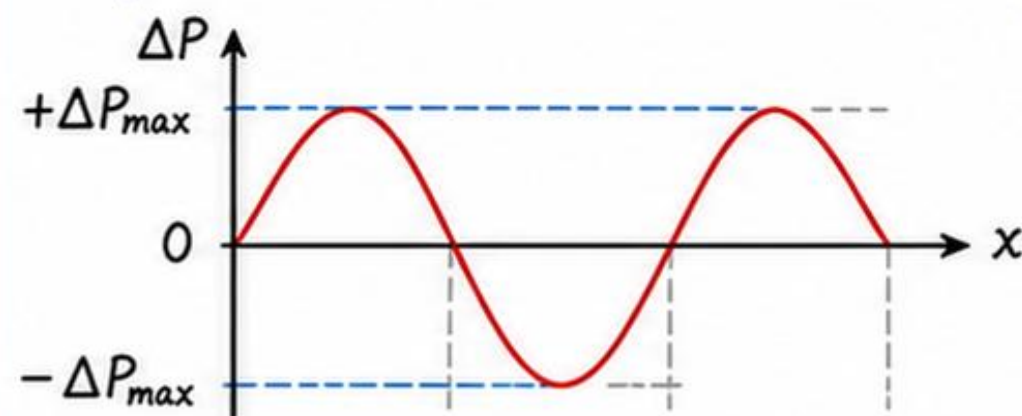
SIDE NOTE

For electromagnetic waves (light), the electric field $E(t)$ and the magnetic field $B(t)$ can serve as displacement variables.



③ DISPLACEMENT IN A SOUND WAVE

pressure variation ΔP about mean pressure P_0 .

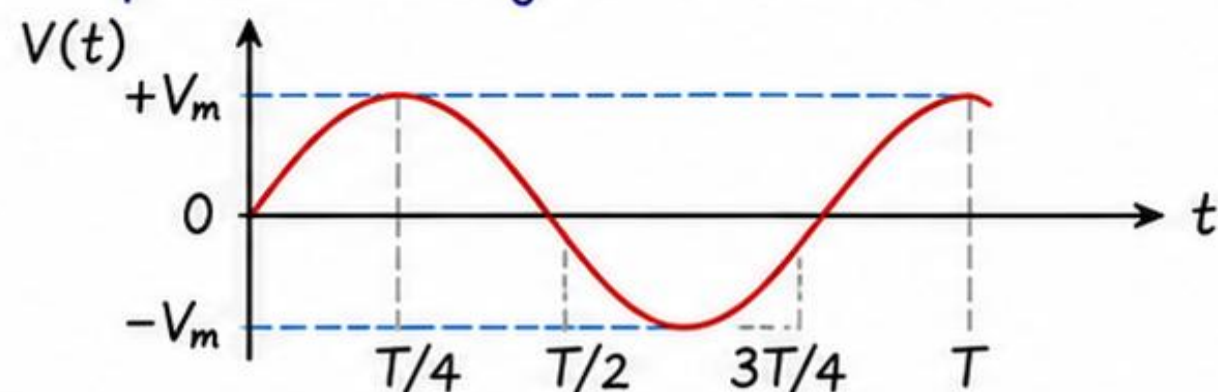


compression:
 $\Delta P > 0$,
pressure above P_0

rarefaction:
 $\Delta P < 0$,
pressure below P_0 .

④ DISPLACEMENT IN AN AC CIRCUIT

instantaneous voltage $V(t)$,
positive and negative about zero.



Choose a convenient mean (**equilibrium or average**) as the origin,
and record the displacement variable as a function of time.

PERIODIC FUNCTIONS

① DEFINITION

A function $f(t)$ is periodic if there exists a positive constant T such that

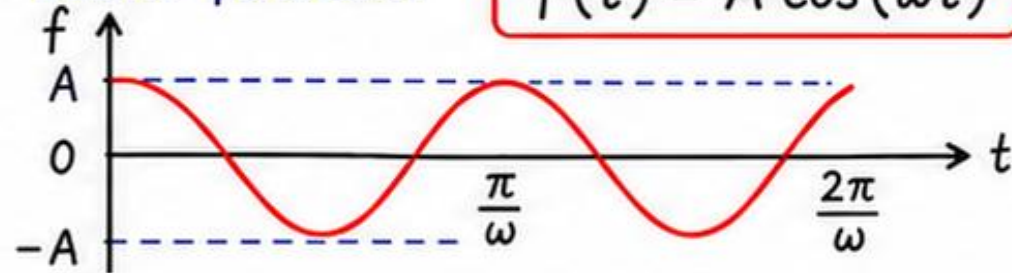
$$f(t+T) = f(t)$$

for all t .

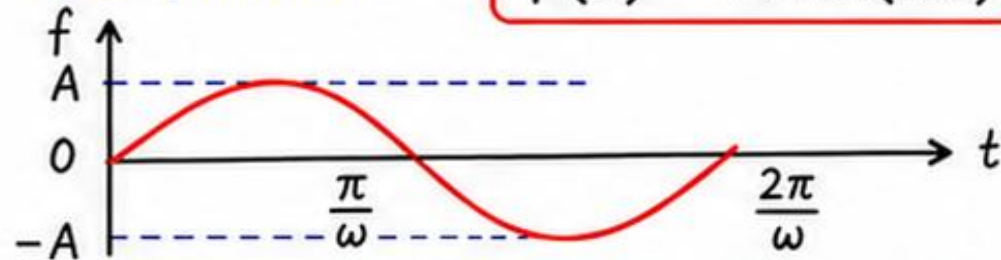
T is called the **least positive period**.

SIMPLE PERIODIC FUNCTIONS

- Cosine function: $f(t) = A \cos(\omega t)$



- Sine function: $f(t) = A \sin(\omega t)$



For both: $T = \frac{2\pi}{\omega}$

② GENERAL FORM

Any function of the form

$$f(t) = A \sin(\omega t) + B \cos(\omega t) = D \sin(\omega t + \phi)$$

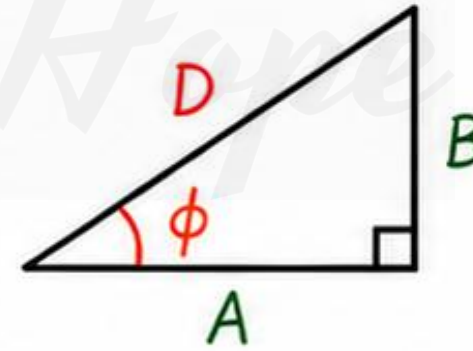
is a periodic function.

Relations between the constants:

$$D = \sqrt{A^2 + B^2}$$

$$A = D \cos \phi$$

$$B = D \sin \phi$$



Since it can be written as $D \sin(\omega t + \phi)$,

$$\text{its period is } T = \frac{2\pi}{\omega}$$

same as sine and cosine.

③ CLASSIFICATION

- A sum of sine and cosine with the same angular frequency is periodic.

$$f(t) = \sin(\omega t) + \cos(\omega t) \Rightarrow T = \frac{2\pi}{\omega}$$

- A sum of terms with angular frequencies that are integer multiples of a common ω is periodic.

$$f(t) = \sin(\omega t) + \cos(2\omega t) + \sin(4\omega t)$$

$$\text{Least period: } T = \frac{2\pi}{\omega}$$

- Functions not expressible as a superposition of sines and cosines of commensurate frequencies are non-periodic.

$$f(t) = e^{-\omega t} \Rightarrow \text{non-periodic}$$

$$f(t) = \log(\omega t) \Rightarrow \text{non-periodic}$$

FOURIER IDEA: Any periodic function, no matter how complicated, can be represented as a **superposition (sum)** of **sine** and **cosine** functions of suitable frequencies.

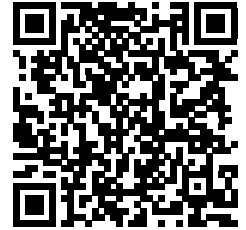


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