

April 29, Week 15

Today: Chapter 14, Periodic Motion

Homework Assignment #11 - Due May 3.

Mastering Physics: 7 questions from chapters 13 and 14.

Mastering Physics: 13.77

Exams will be graded by Wednesday.

Periodic Motion

Periodic Motion or Oscillation - Any repeated motion.

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Unit: $\frac{1}{s} = Hz$ (Hertz)

Simple Harmonic Motion

Simple Harmonic Motion (SHM) - The simplest type of periodic motion. Occurs when a mass is connected to a spring with no friction.

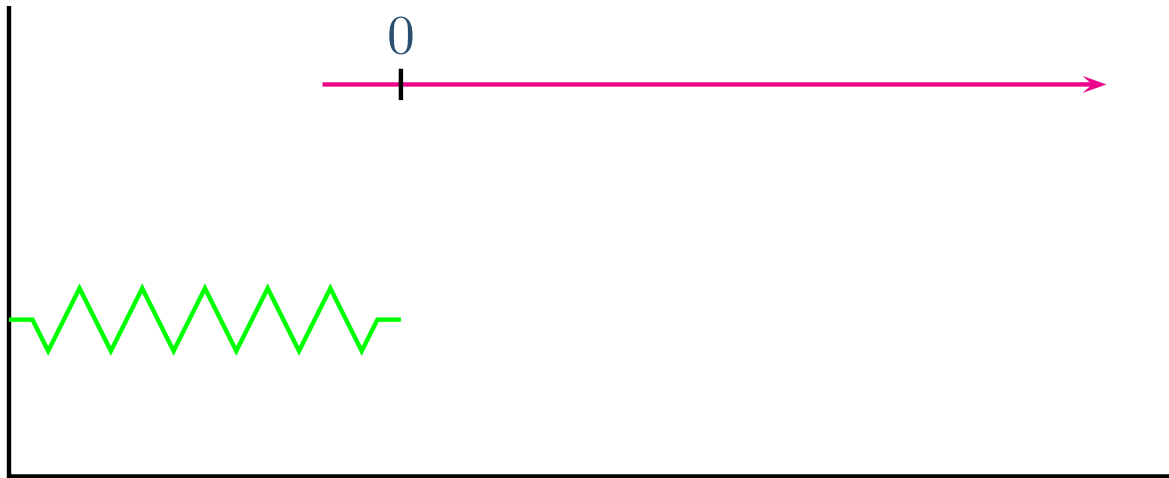
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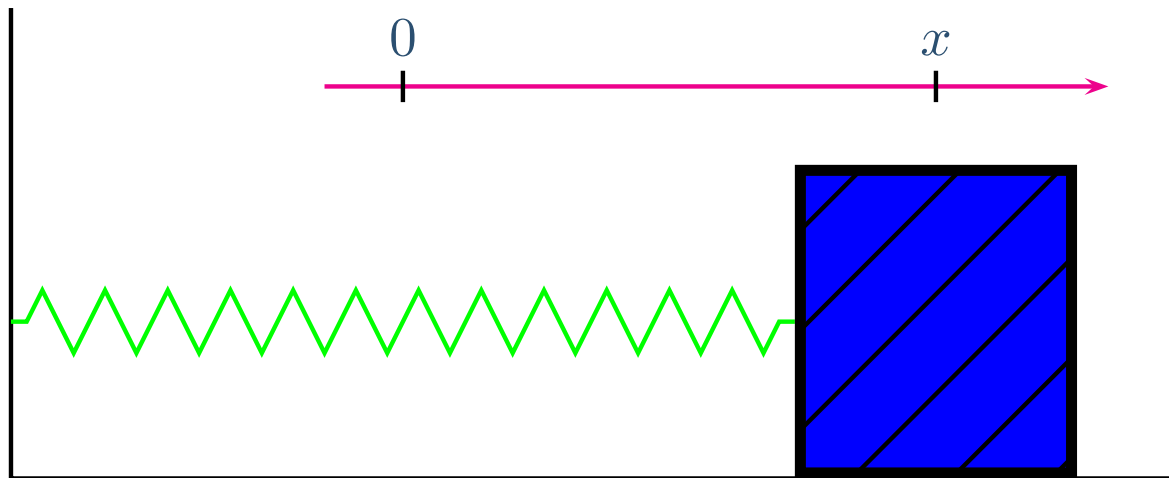
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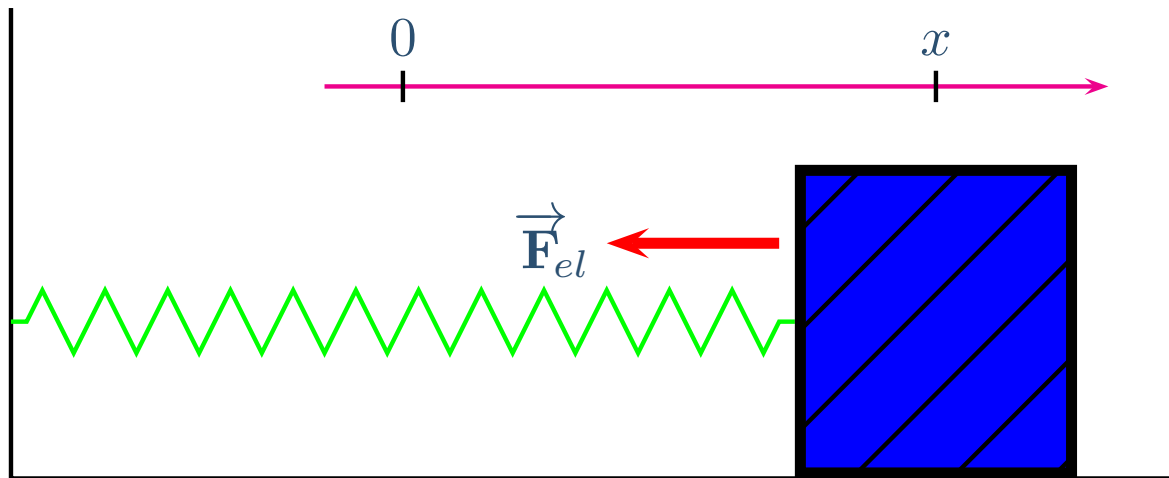
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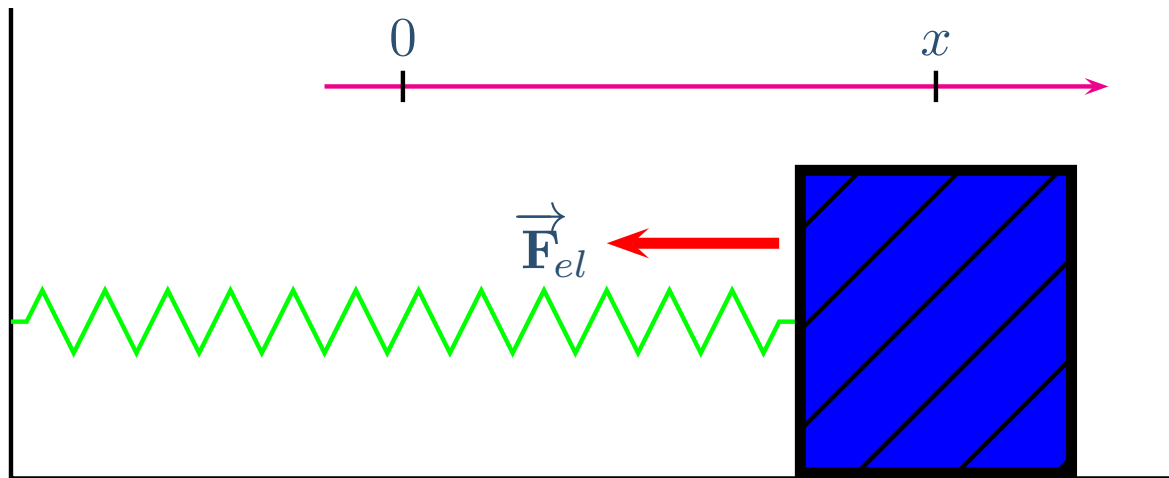
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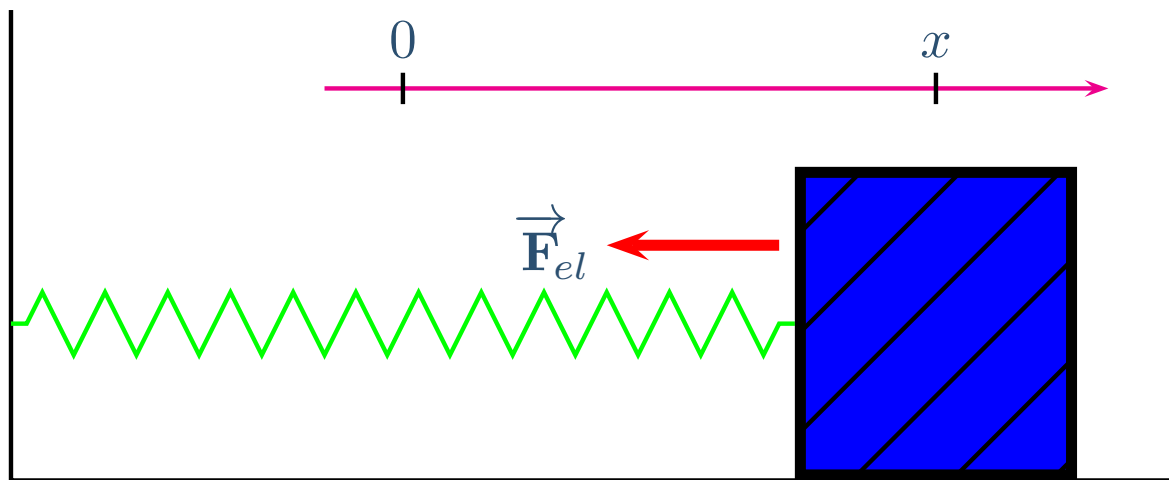
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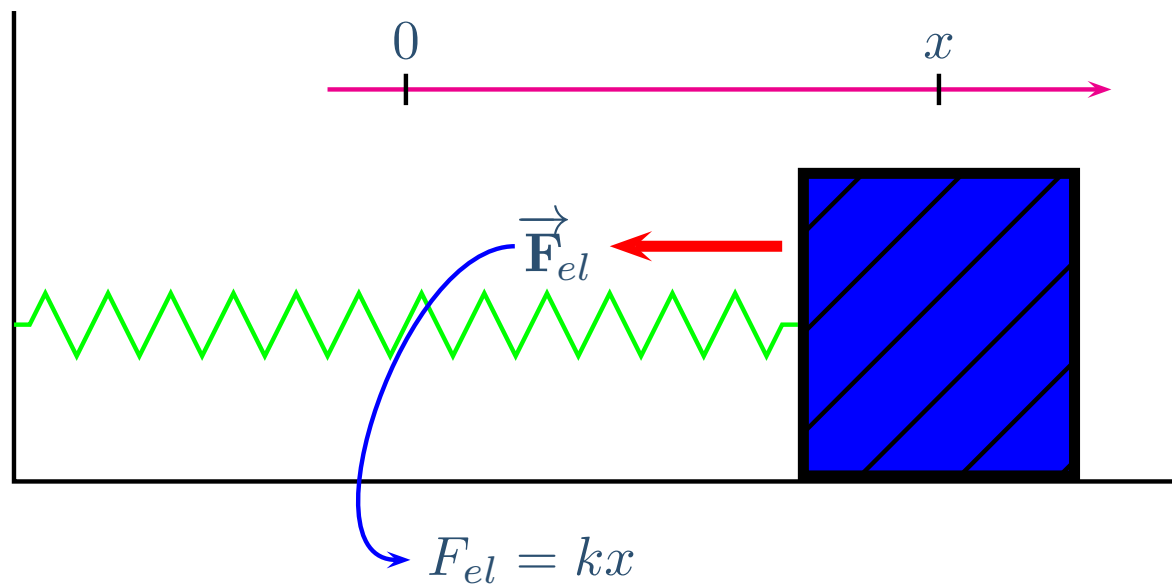


$$\sum \vec{F} = m \vec{a}$$

$$-F_{el} = ma_x$$

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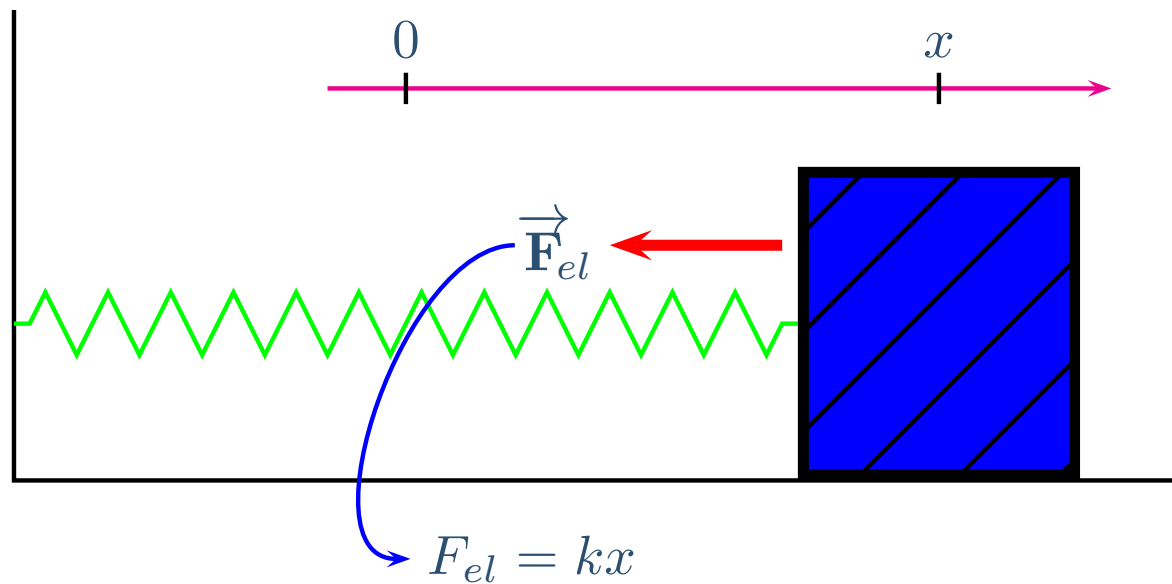


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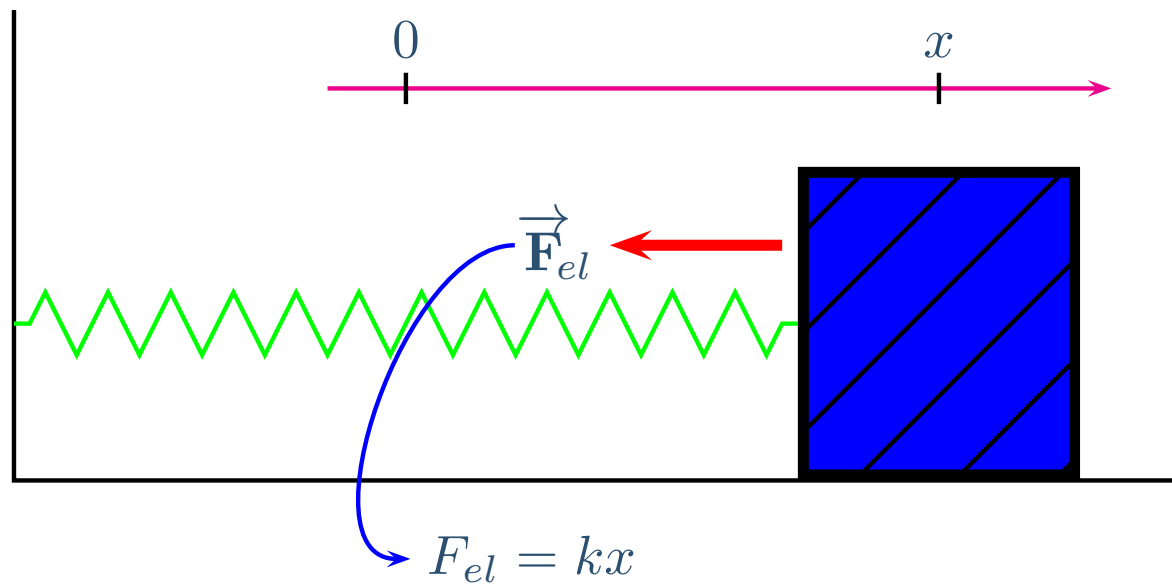
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$$-kx = ma_x$$

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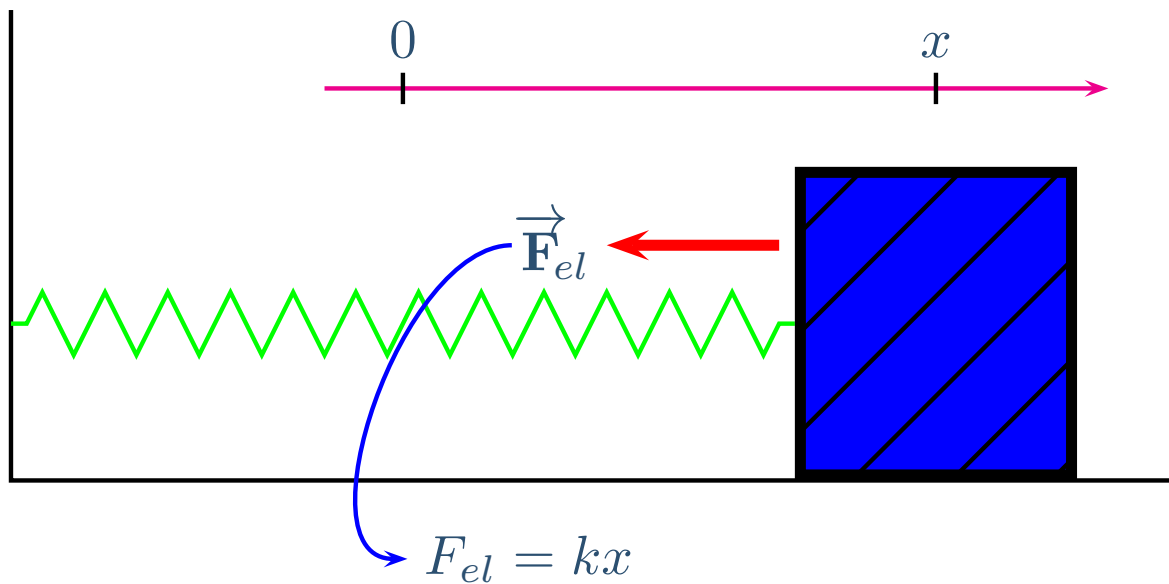
$$-kx = ma_x$$

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

Simple Harmonic Motion II

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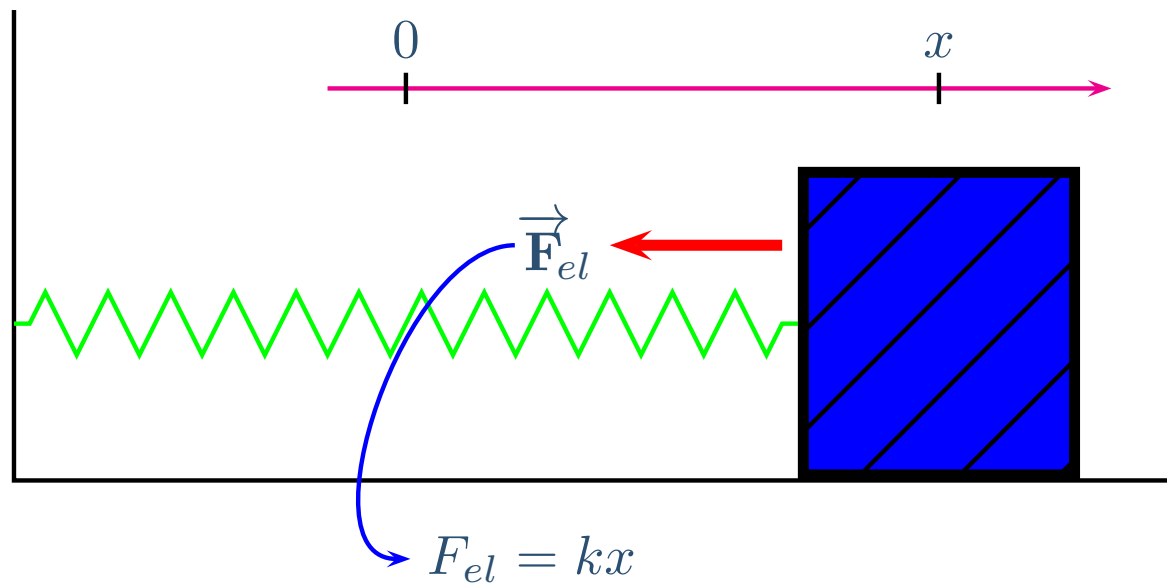
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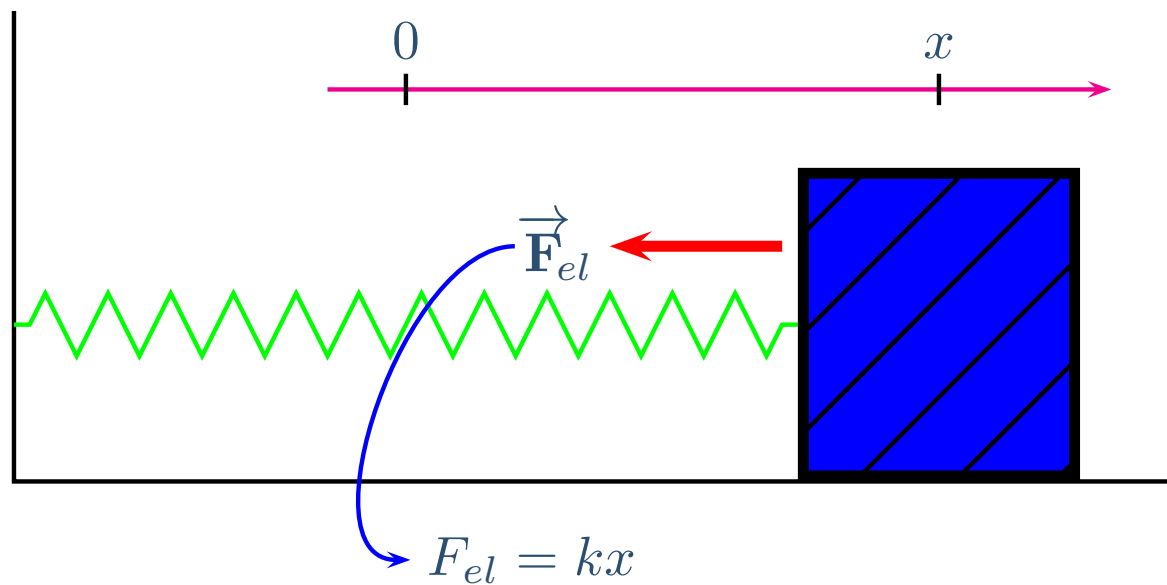


$$v_x = \frac{dx}{dt}$$

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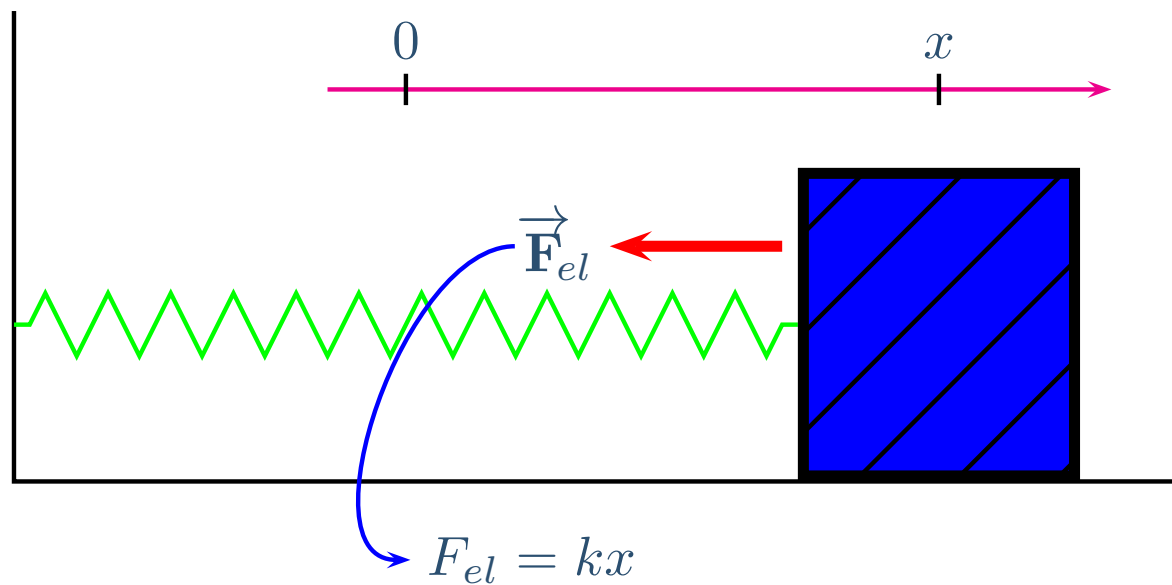


$$a_x = \frac{dv_x}{dt}$$

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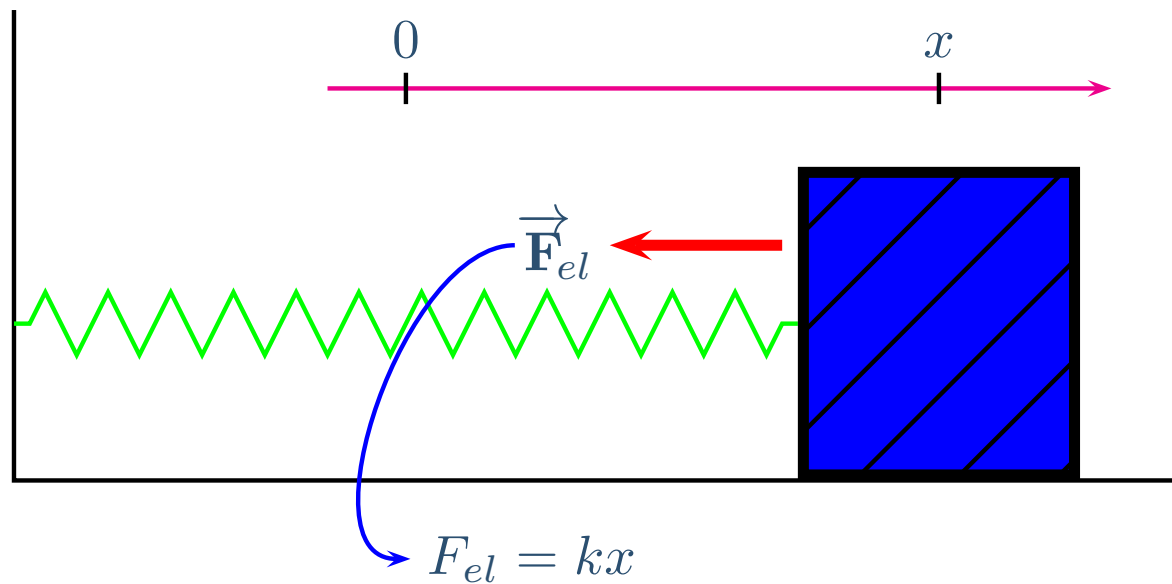
$$a_x = \frac{d^2x}{dt^2}$$

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Simple Harmonic Motion III

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$$-kx = m \frac{d^2x}{dt^2}$$

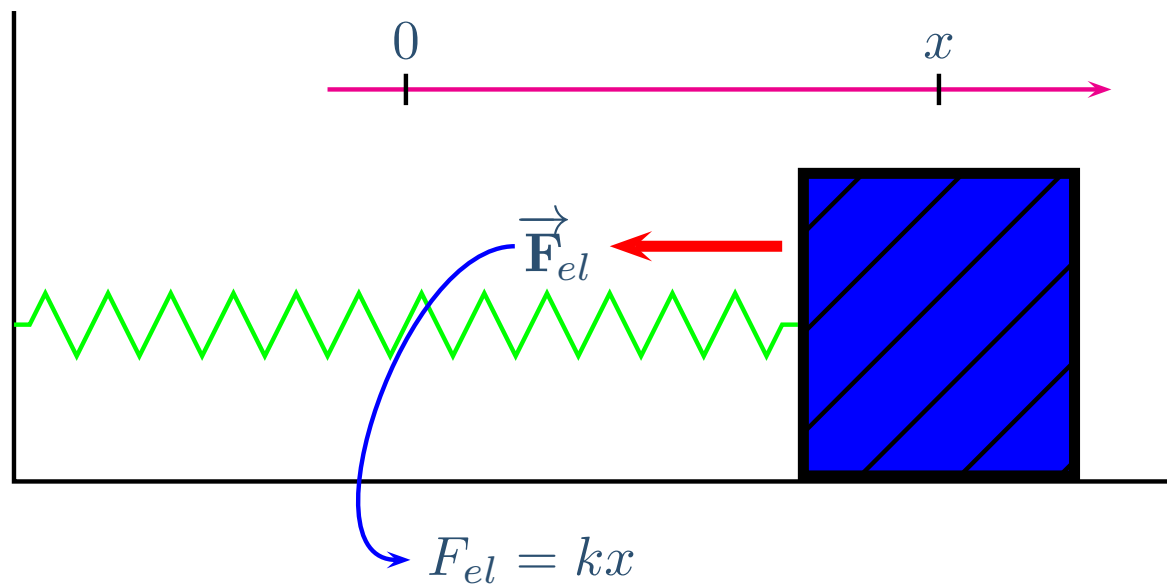
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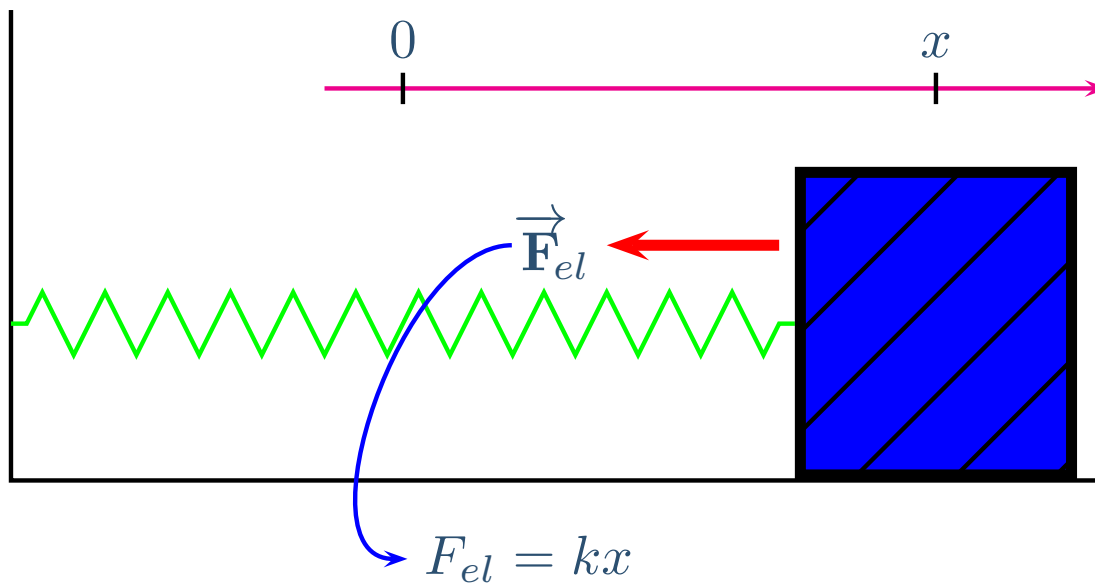
$$\frac{d^2x}{dt^2} = - \left(\frac{k}{m} \right) x$$

Differential Equation
for SHM

Simple Harmonic Motion IV

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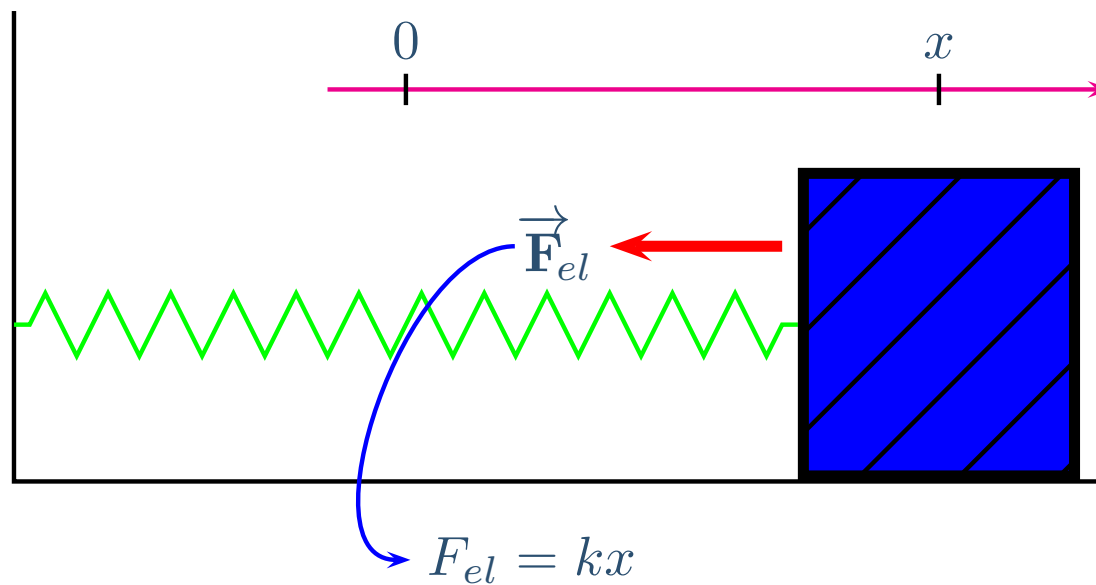
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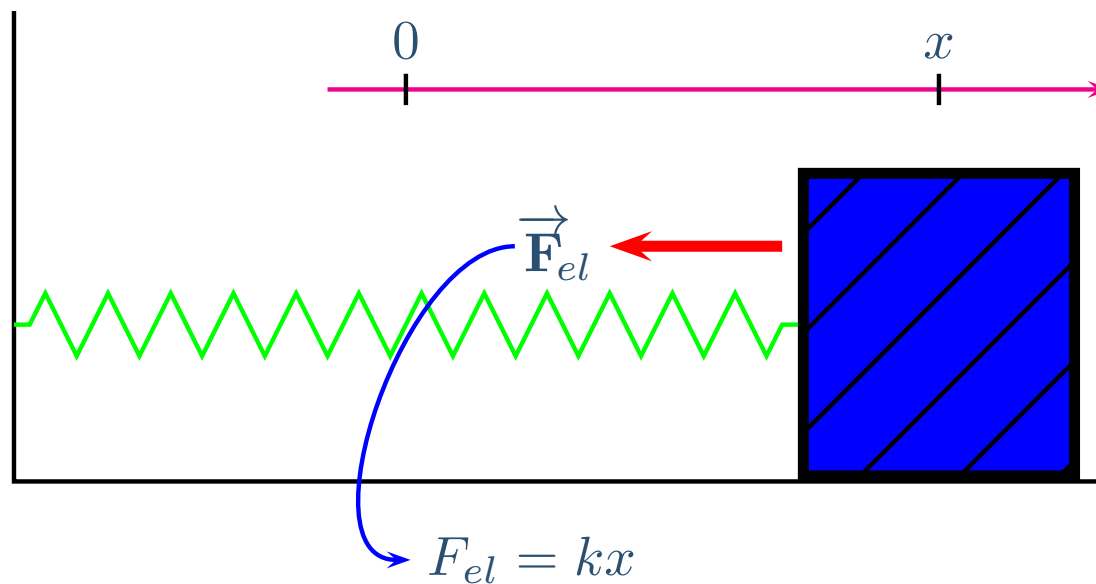


In Calculus: $f'' = -cf$

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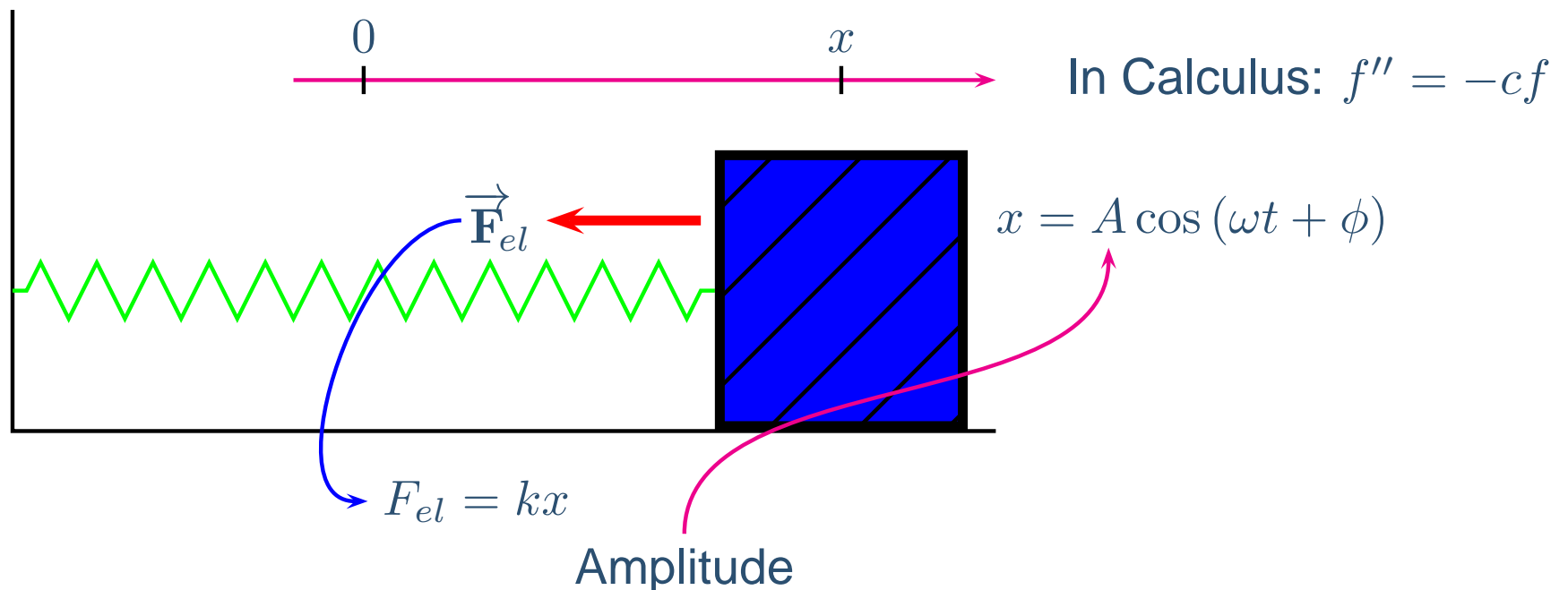
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$$x = A \cos(\omega t + \phi)$$

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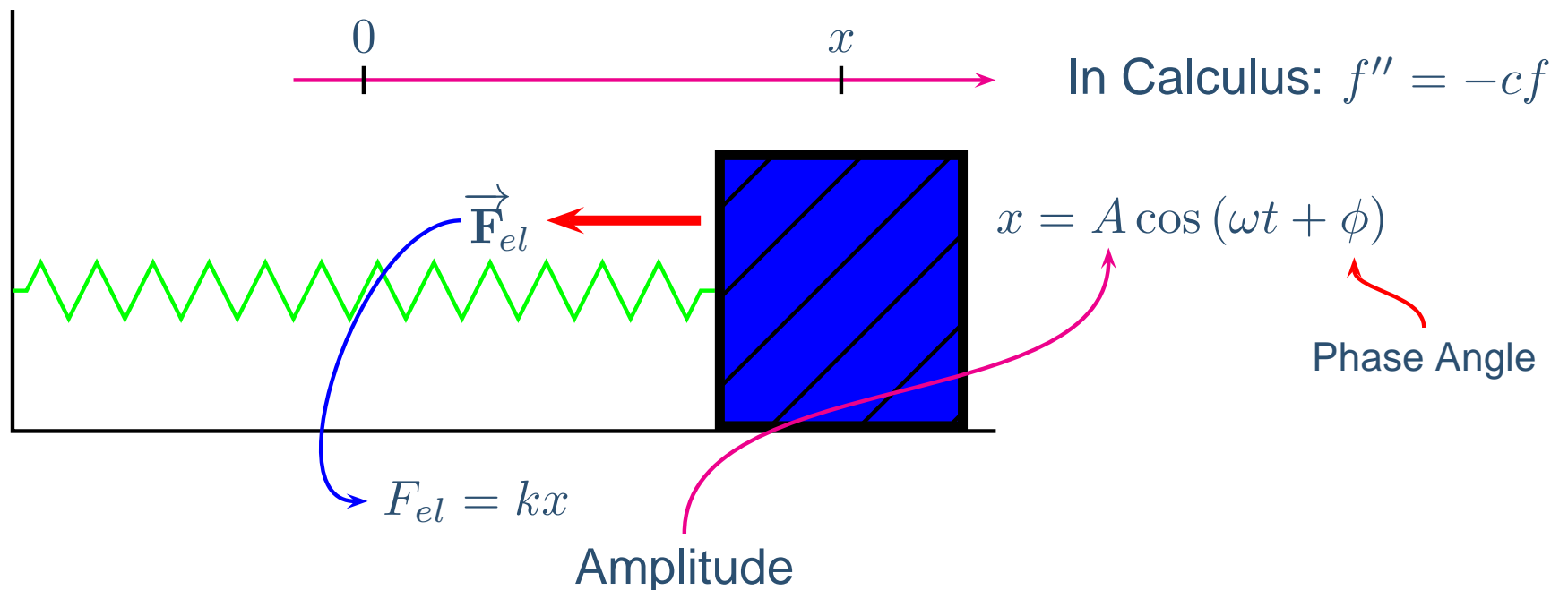
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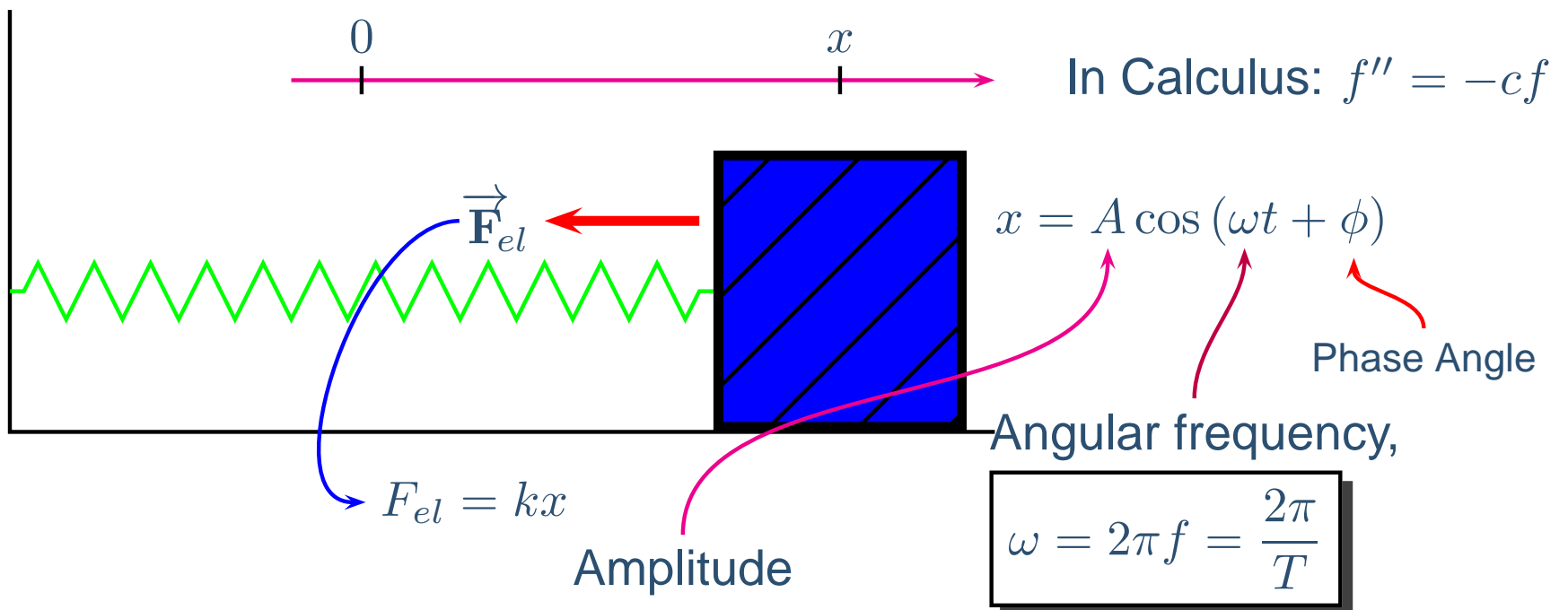
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Amplitude - Maximum distance from zero.

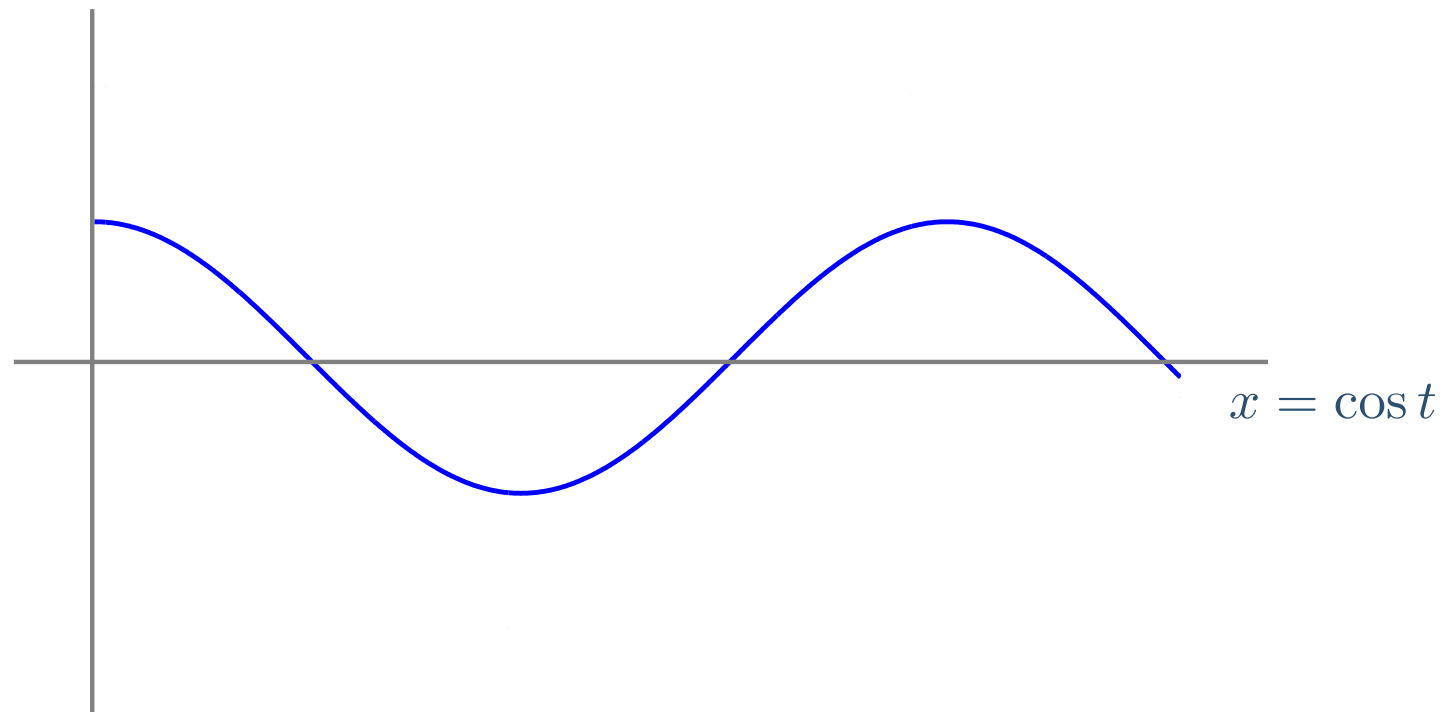
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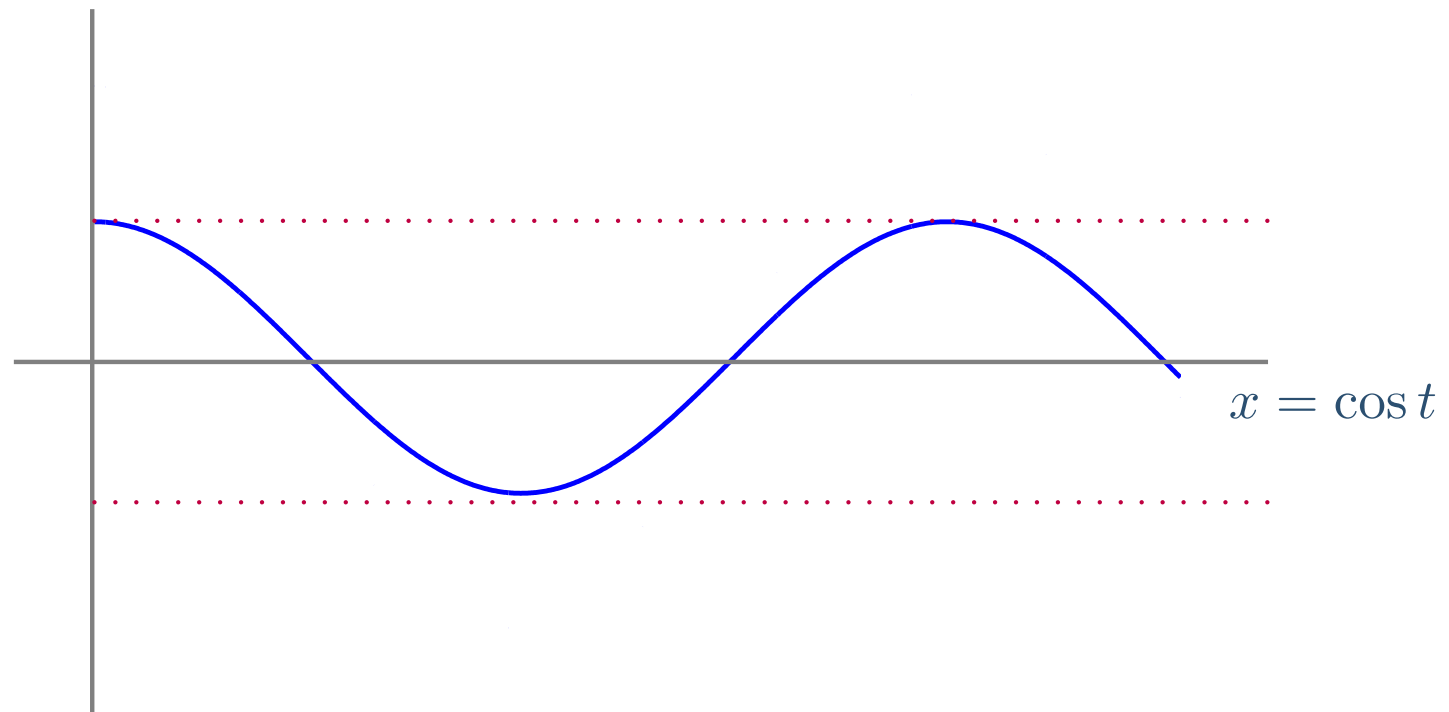
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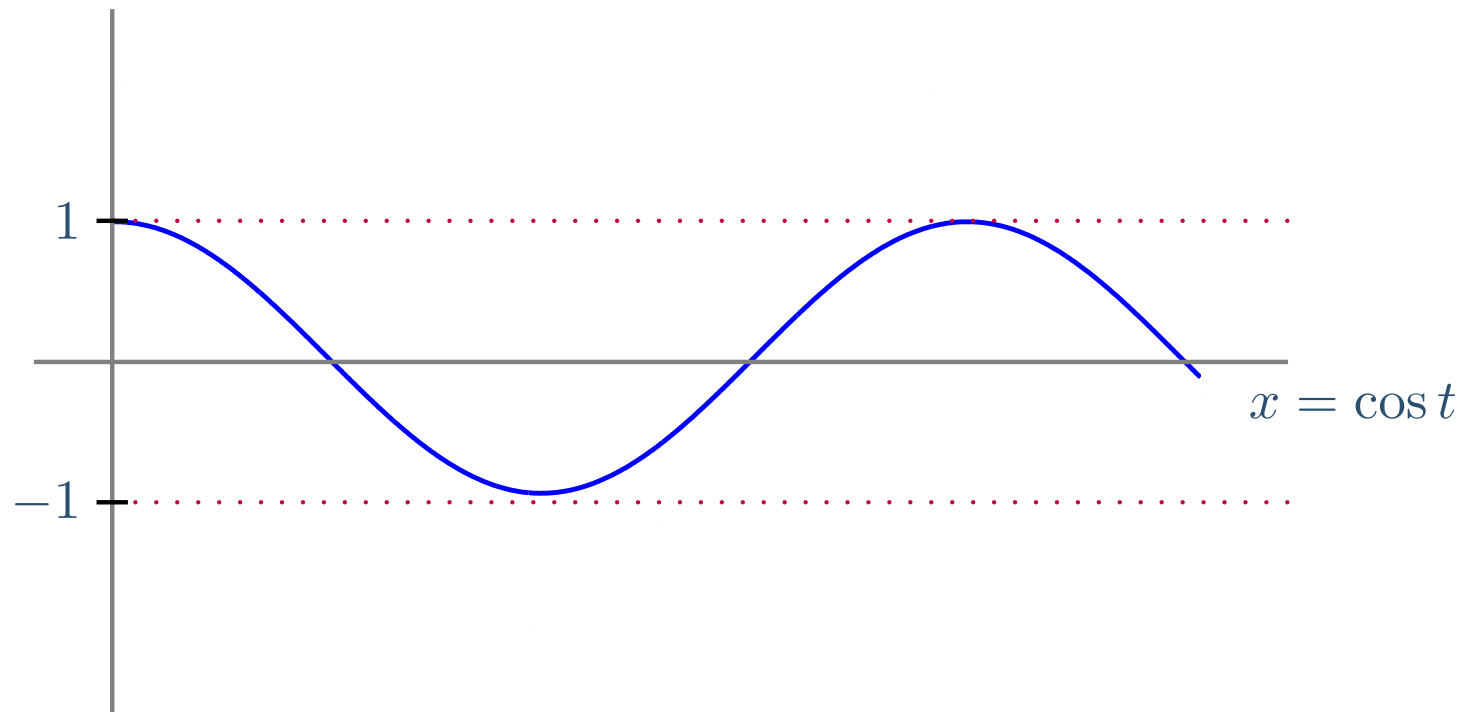
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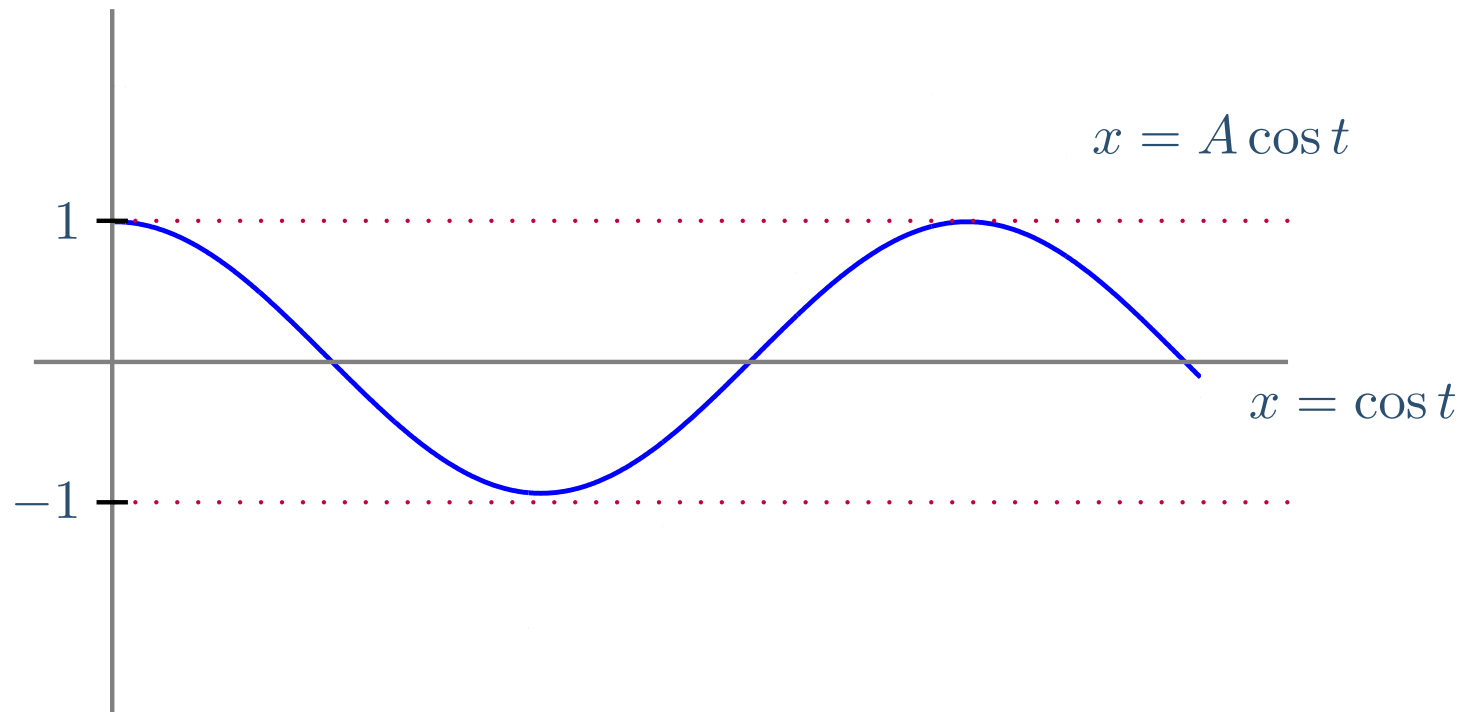
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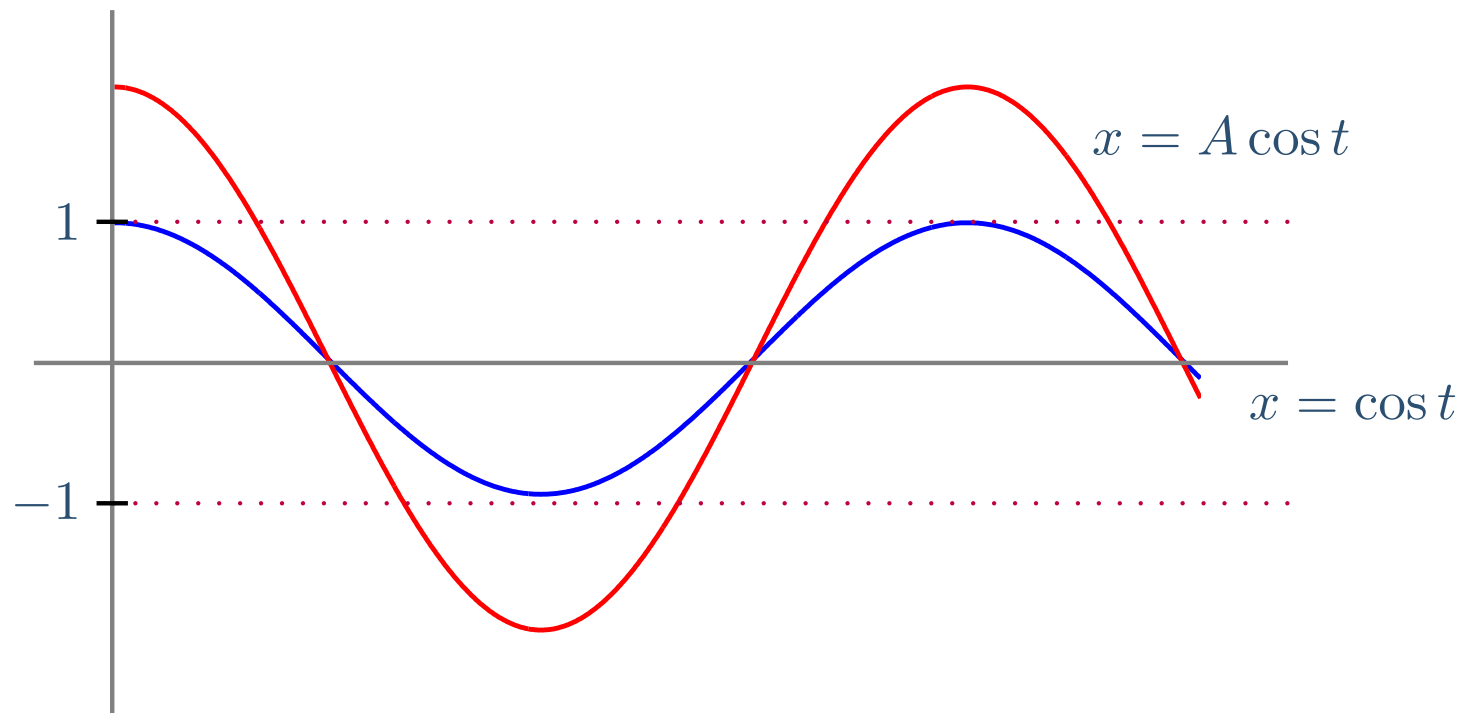
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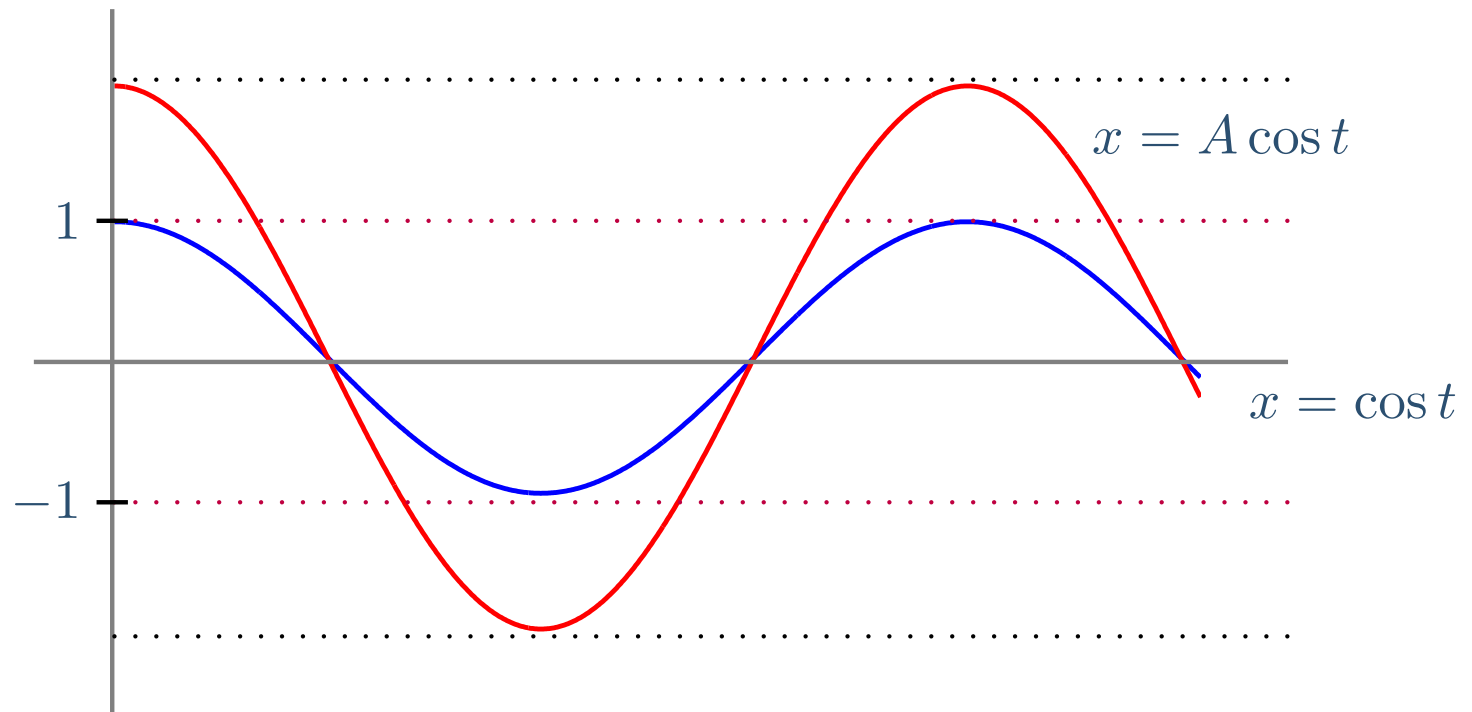
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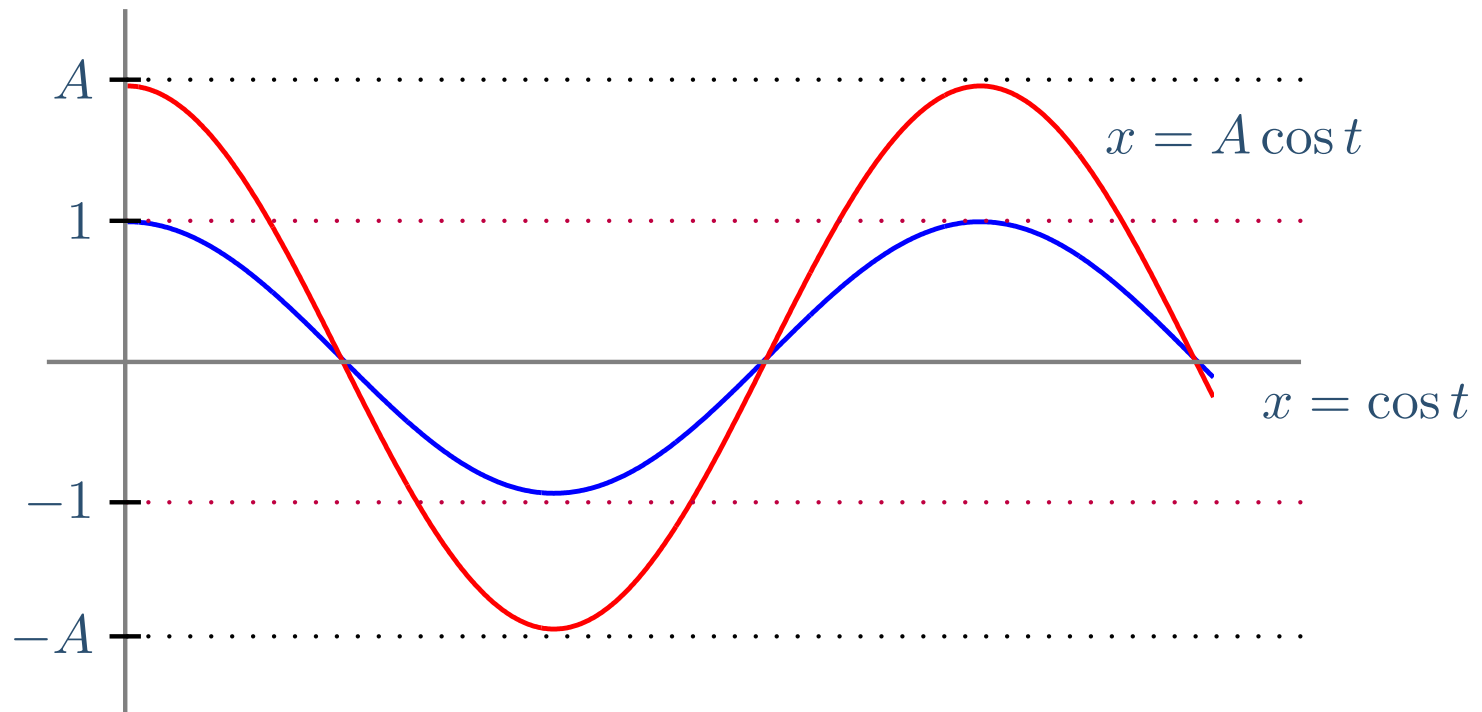
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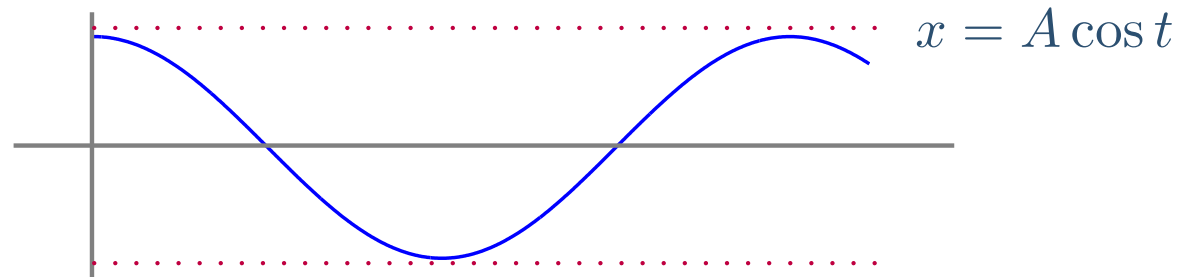


Phase Angle

Phase Angle - ϕ , Units: *rad*. Shifts the Cosine to start wherever needed.

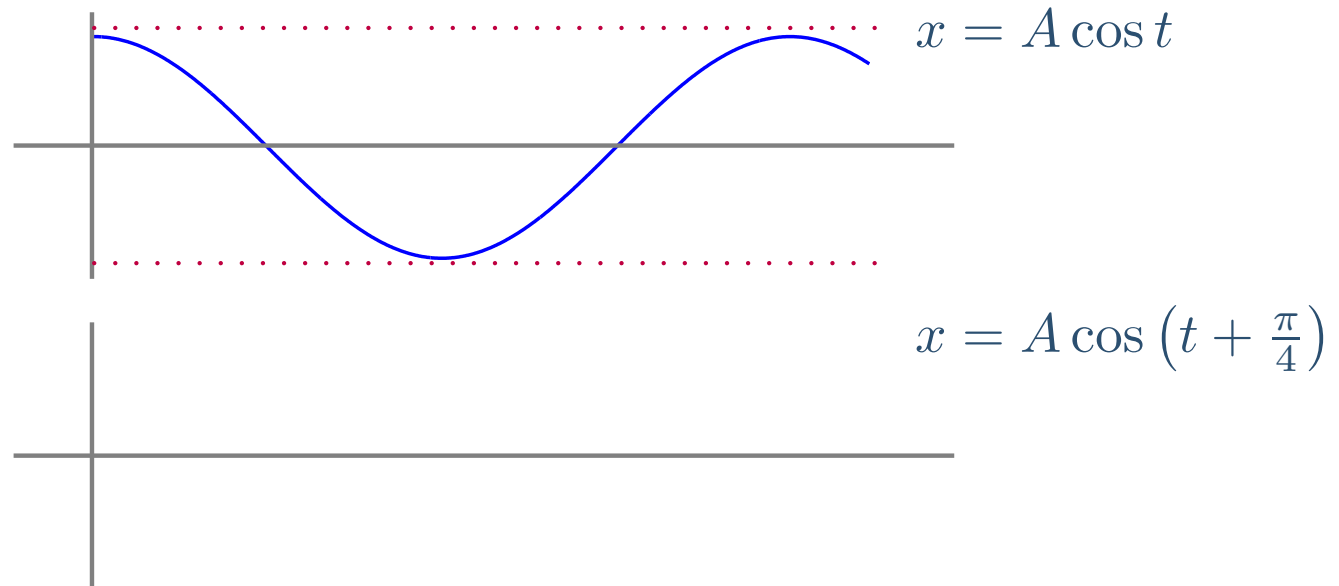
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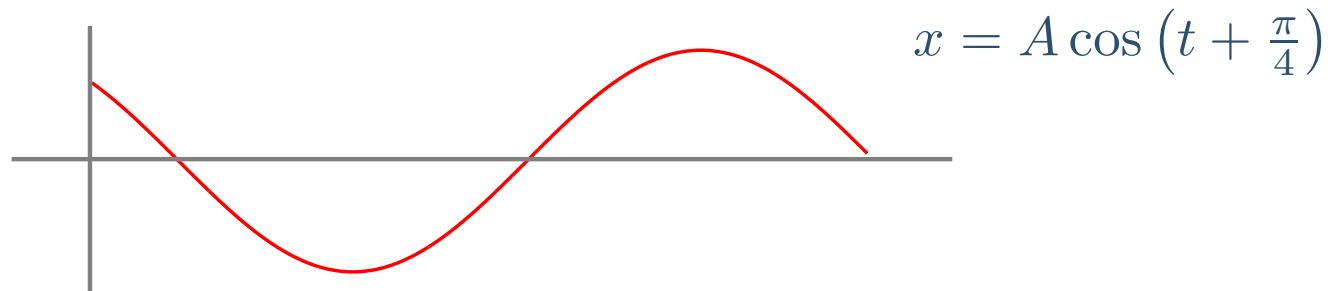
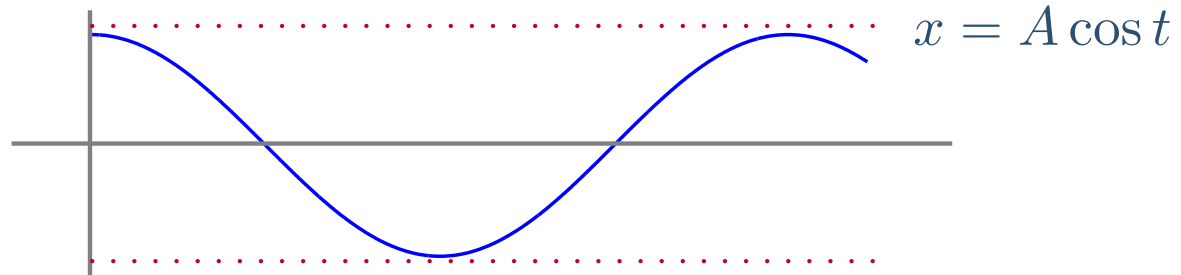
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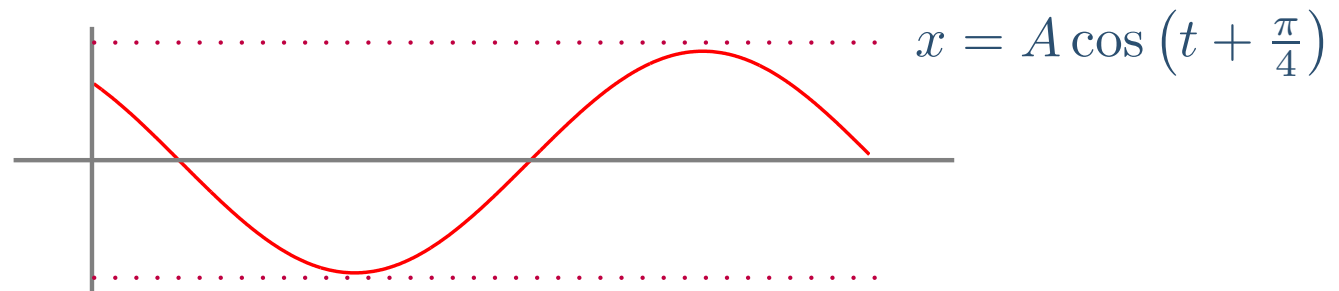
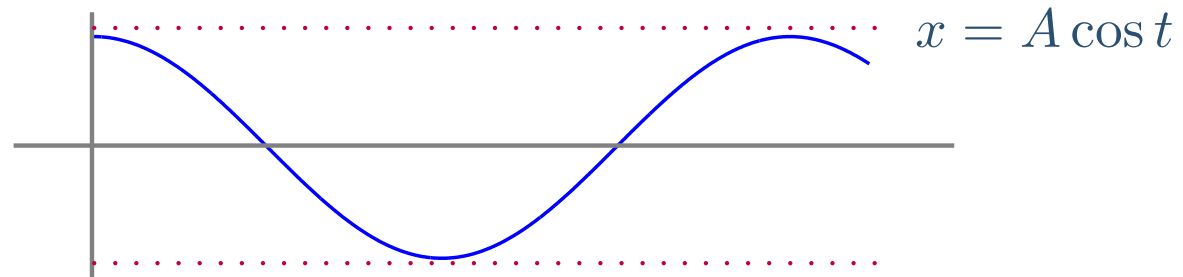
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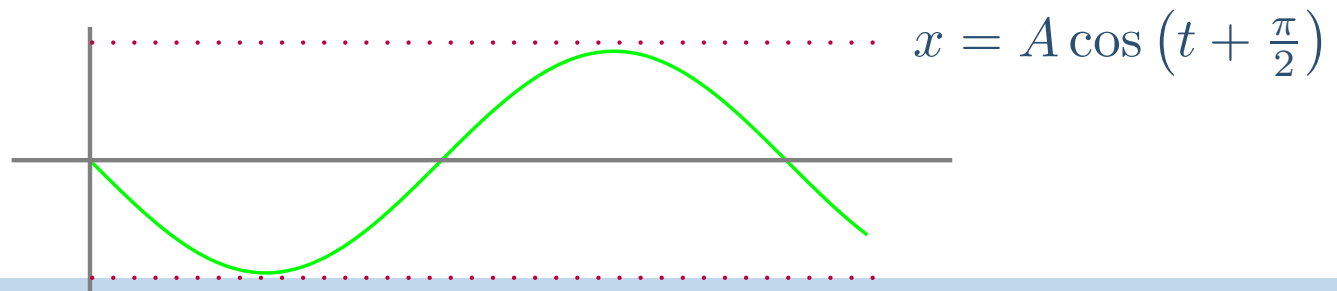
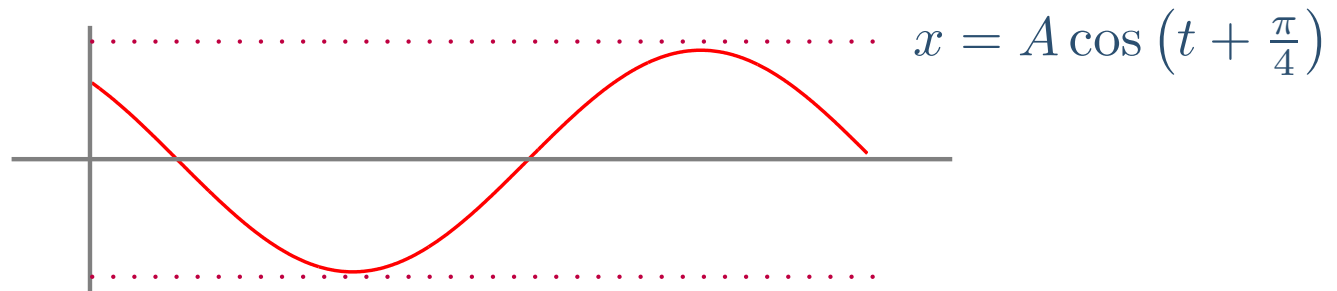
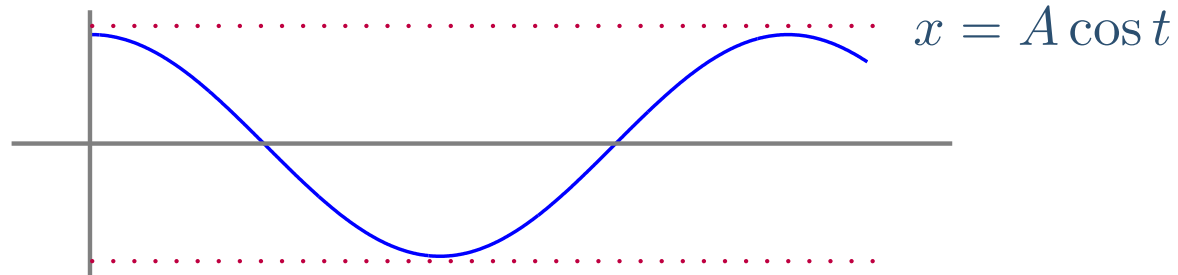
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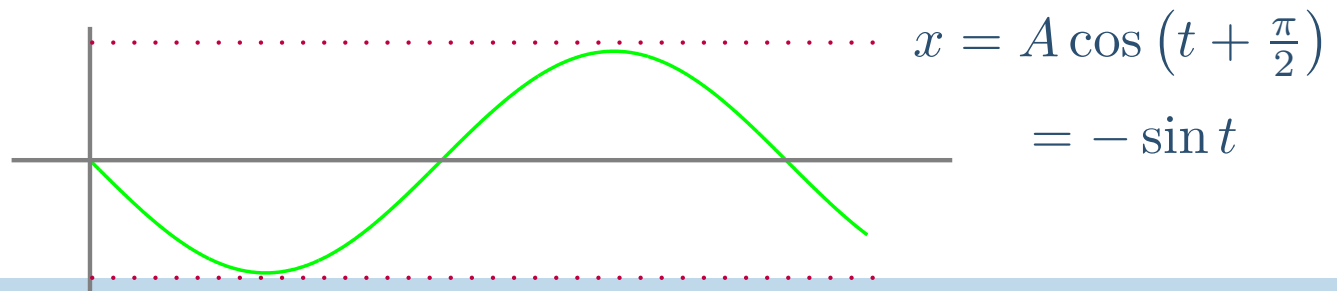
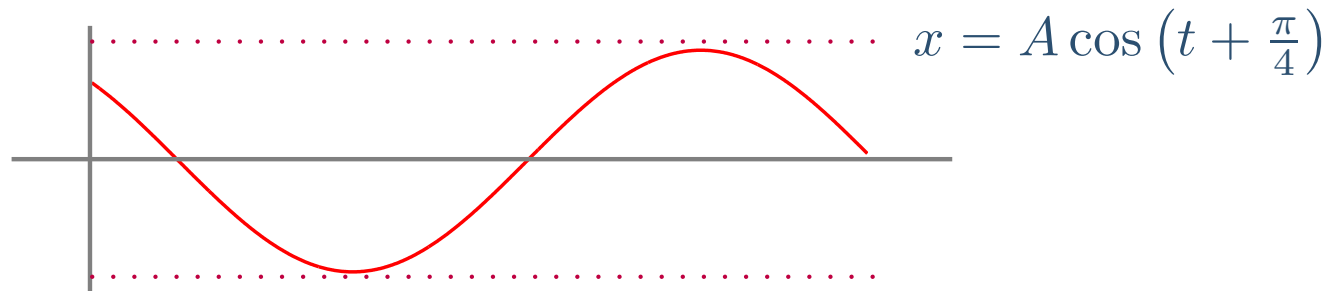
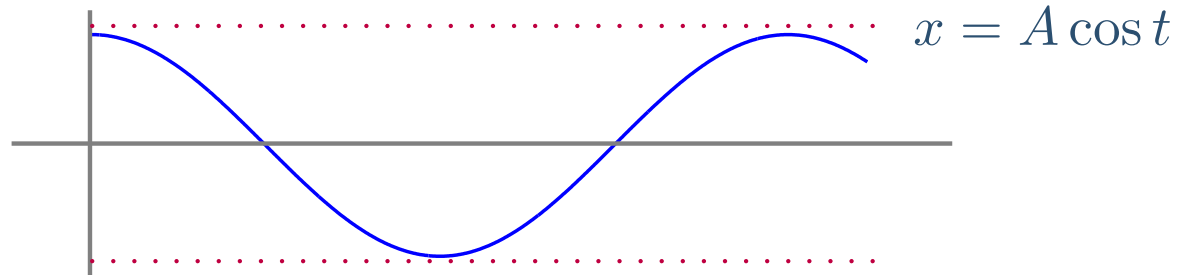
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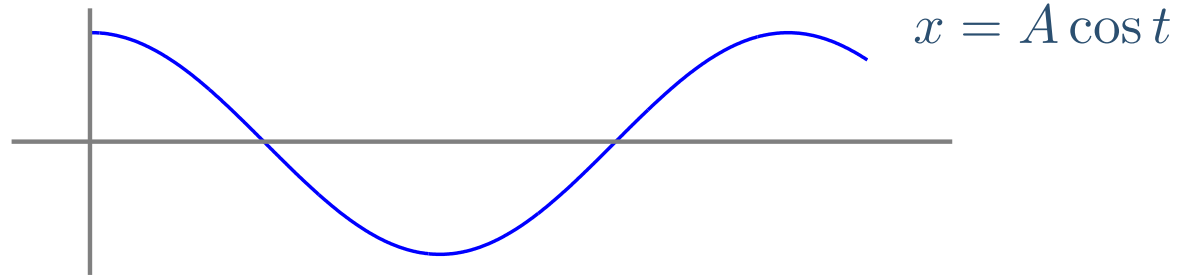


Angular Frequency

Angular Frequency - $\omega = 2\pi f = \frac{2\pi}{T}$ Units: *rad/s*

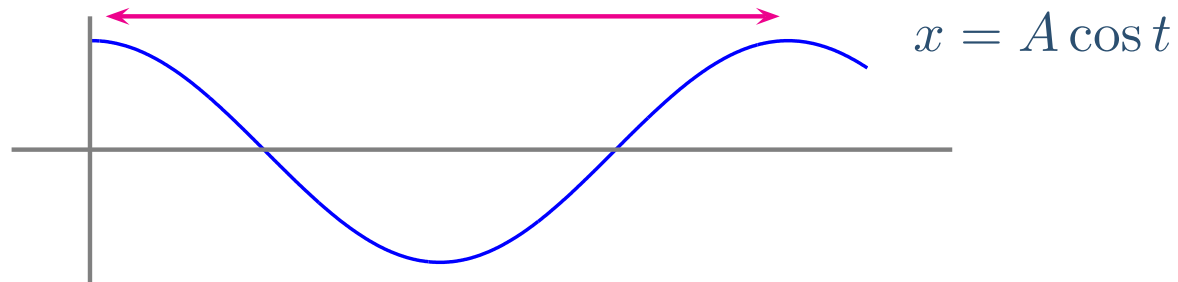
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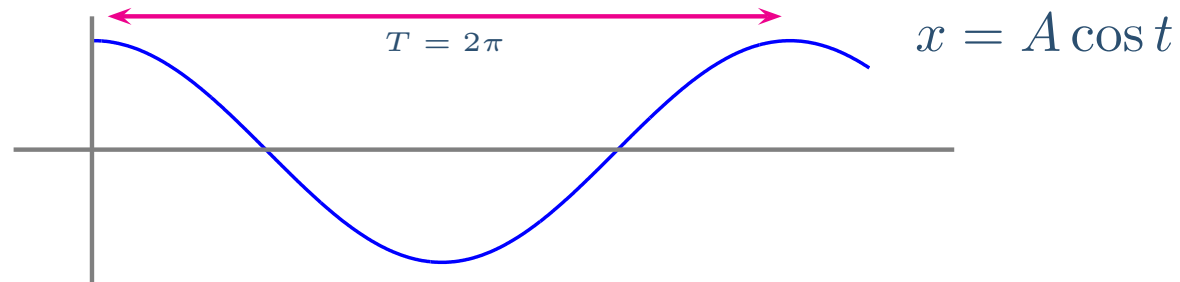
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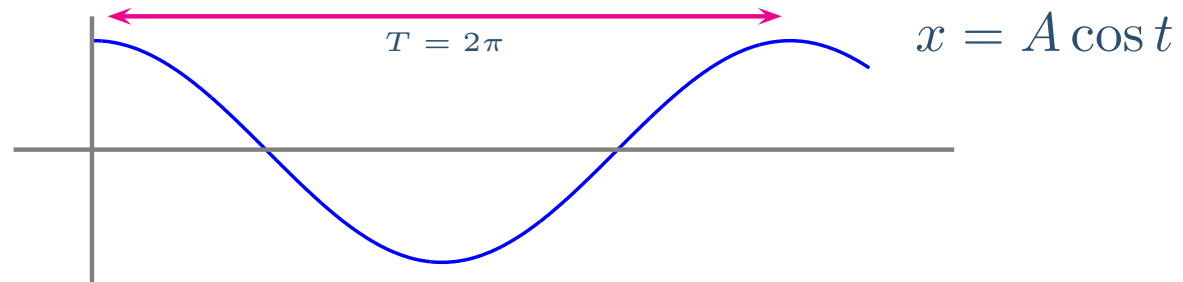
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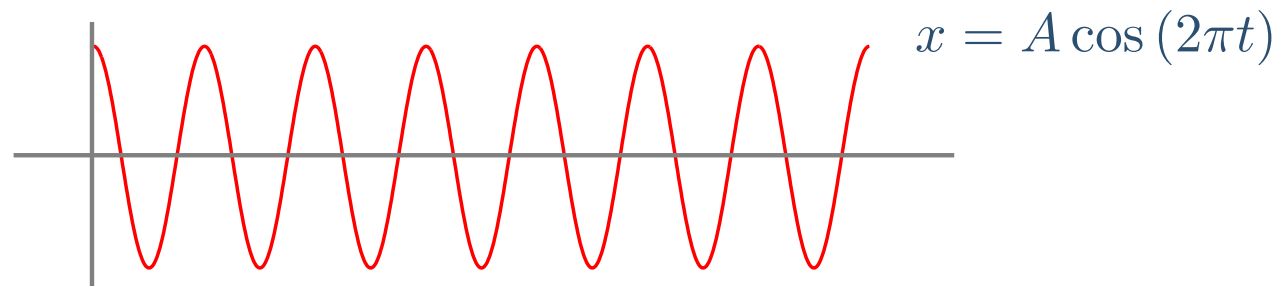
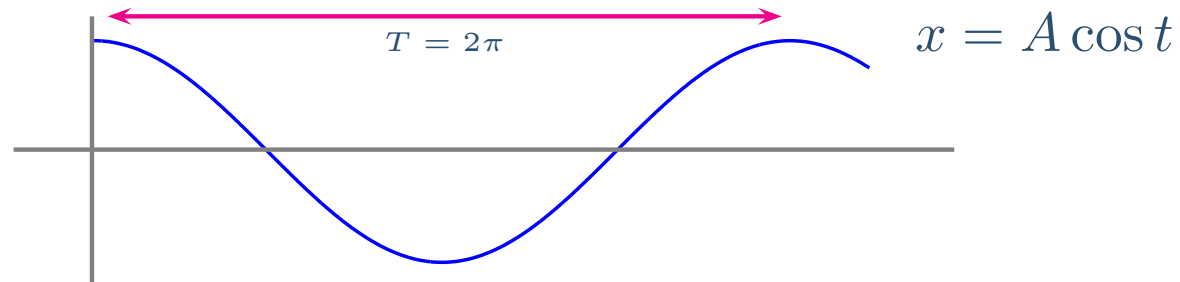
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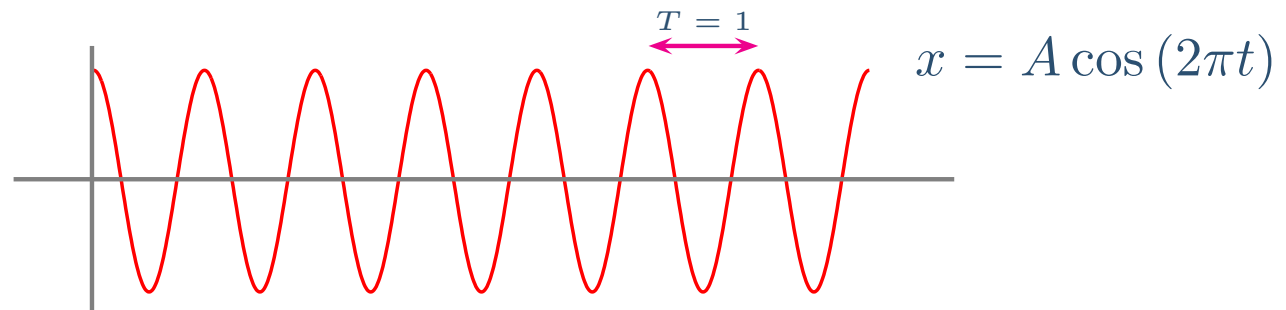
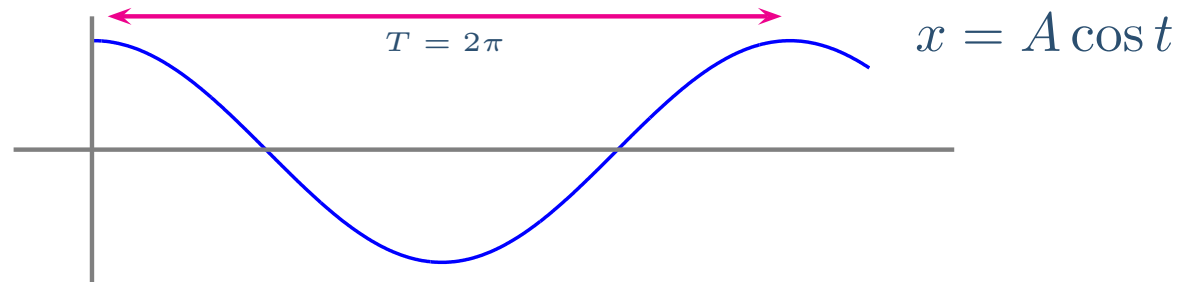
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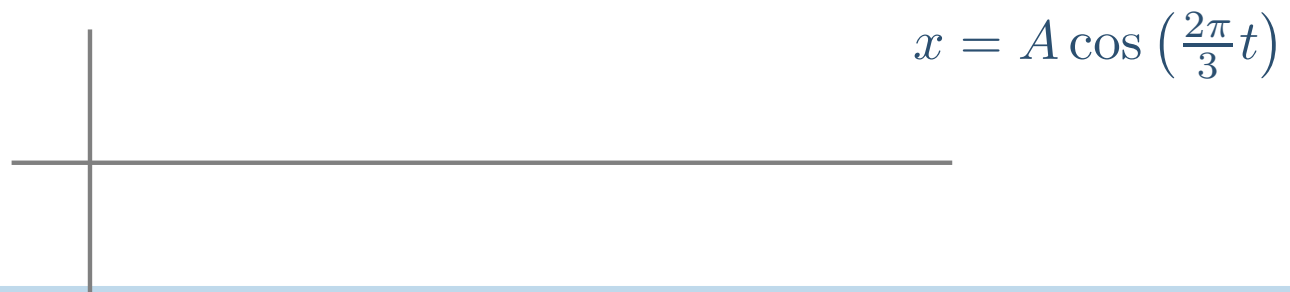
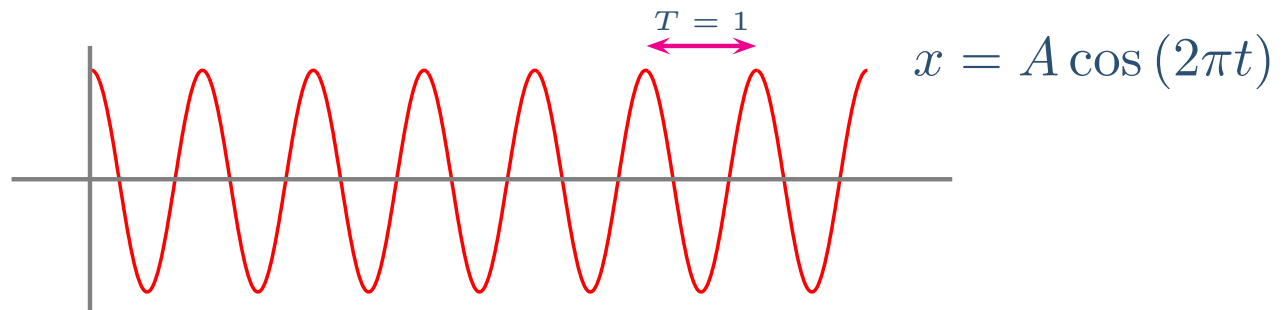
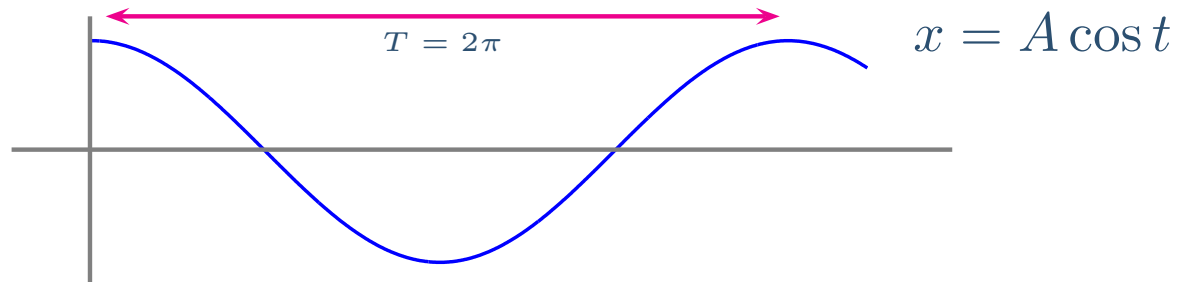
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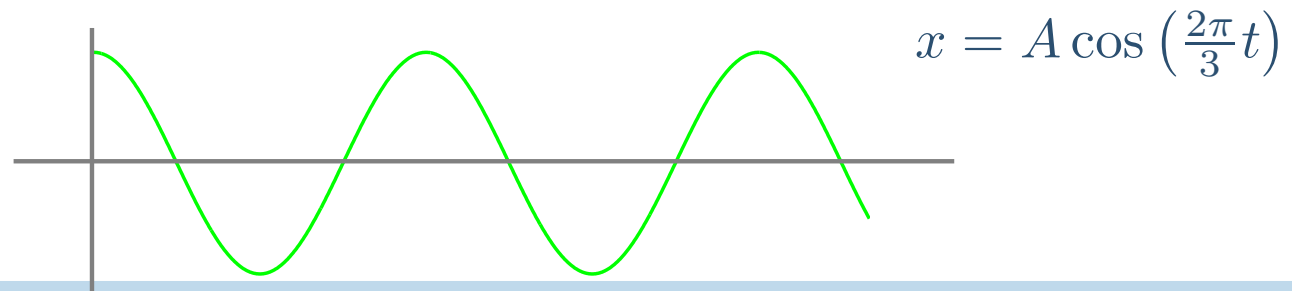
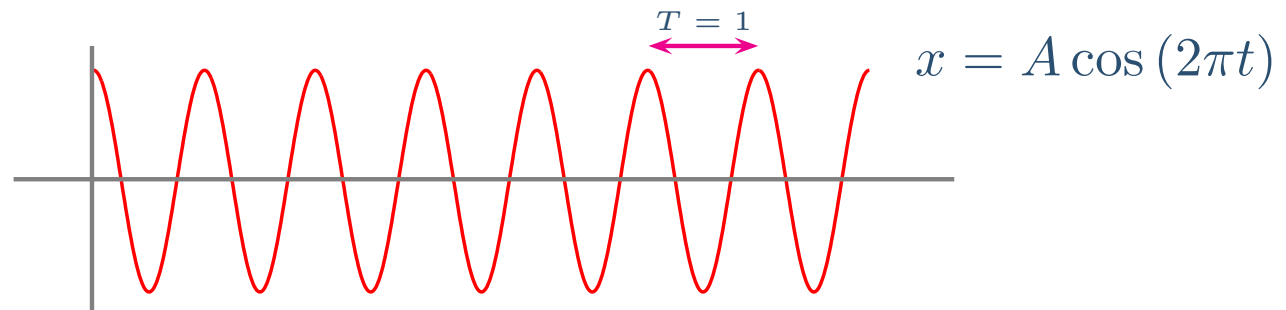
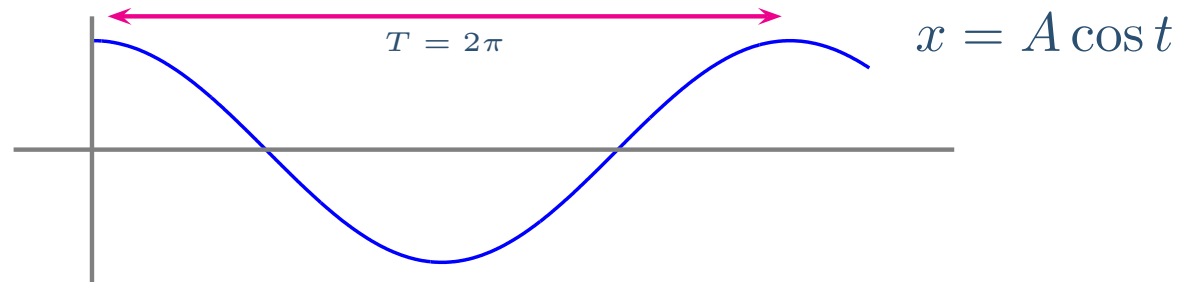
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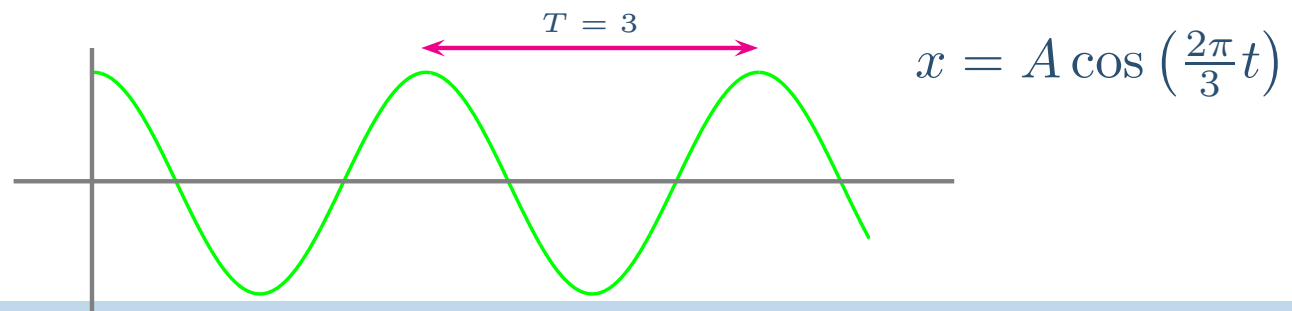
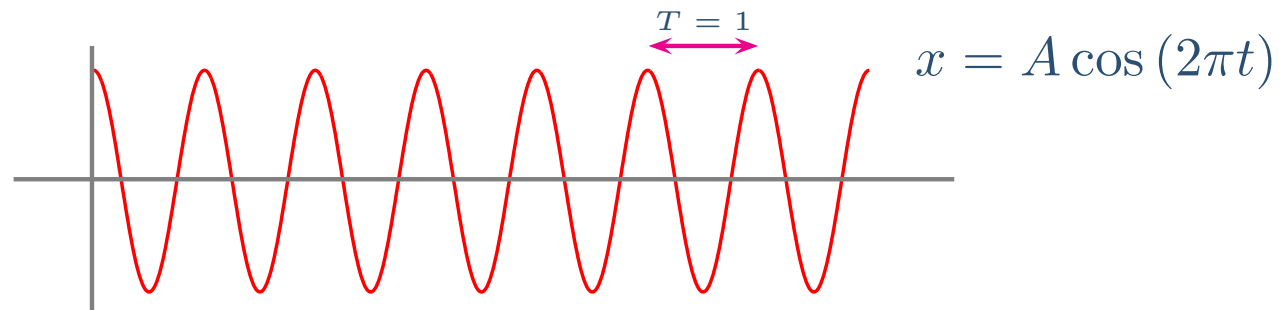
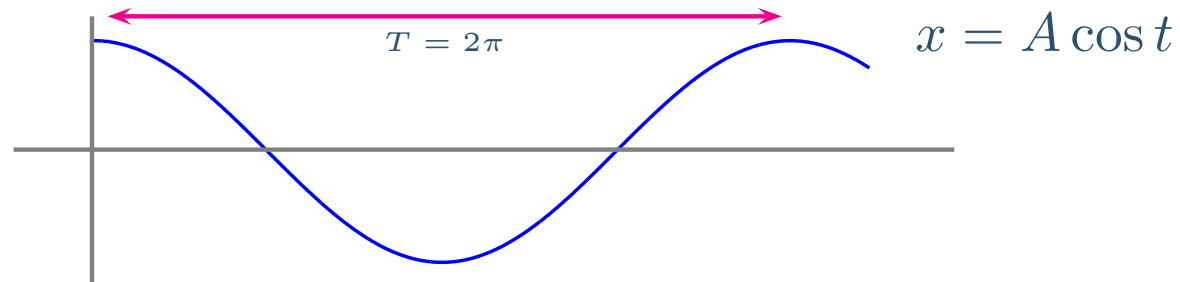
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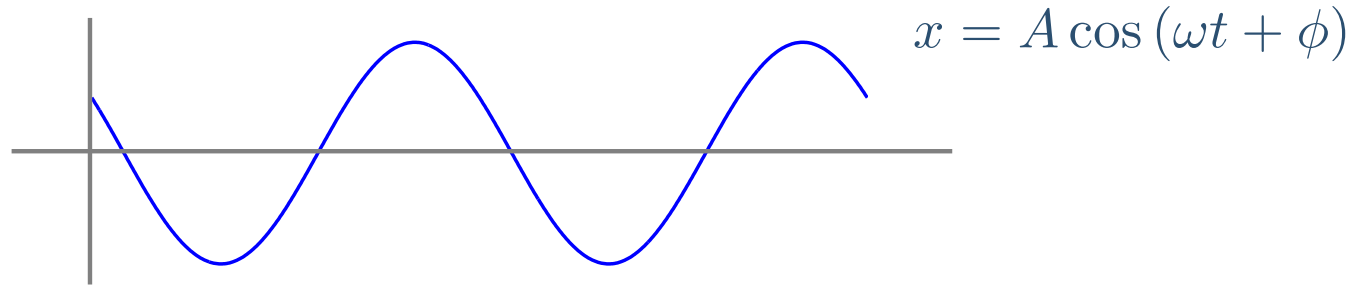
General Solution

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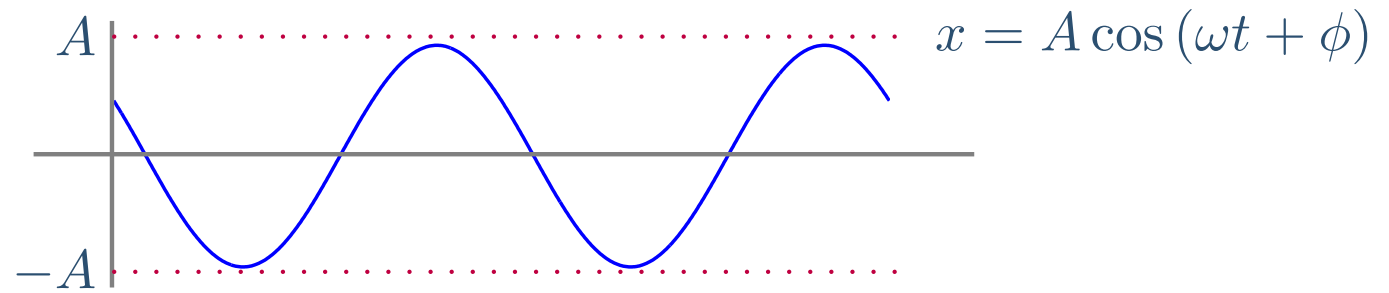


$$x = A \cos(\omega t + \phi)$$

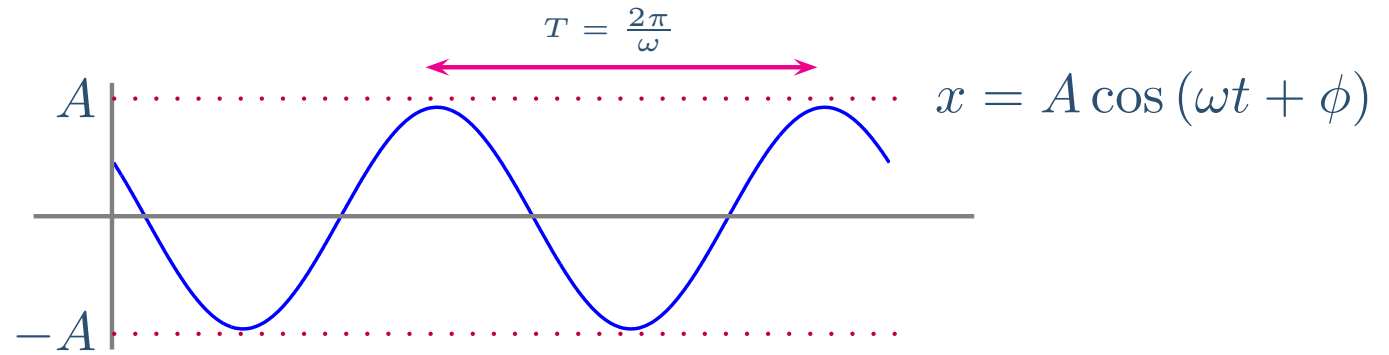
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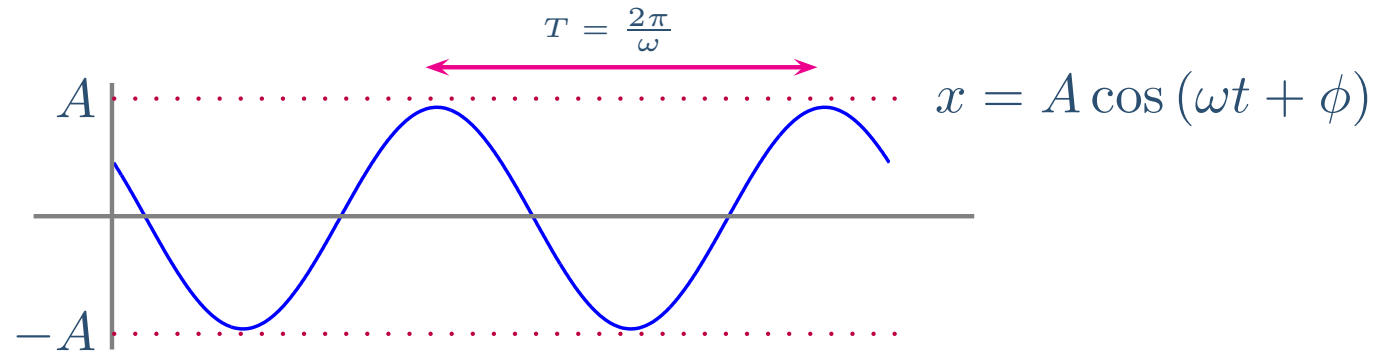
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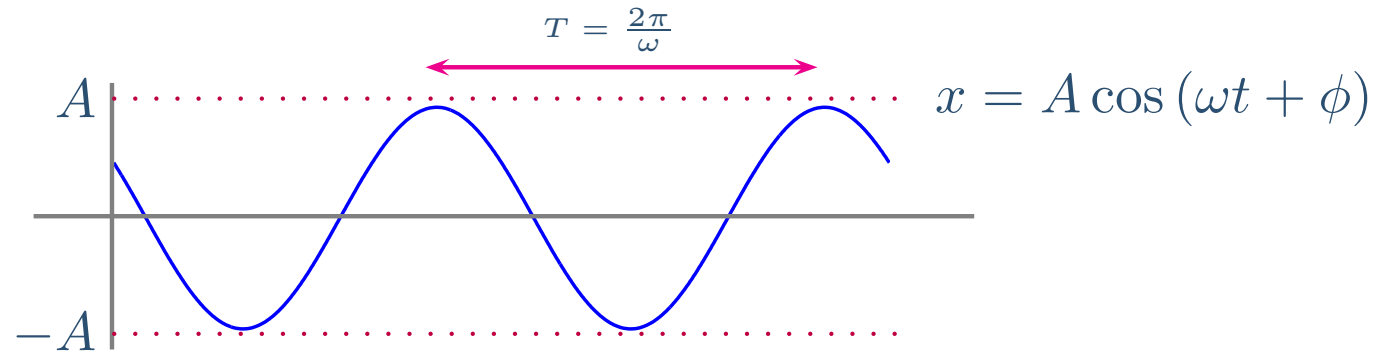


General Solution



Differential Equation for SHM:
$$\frac{d^2x}{dt^2} = - \left(\frac{k}{m} \right) x$$

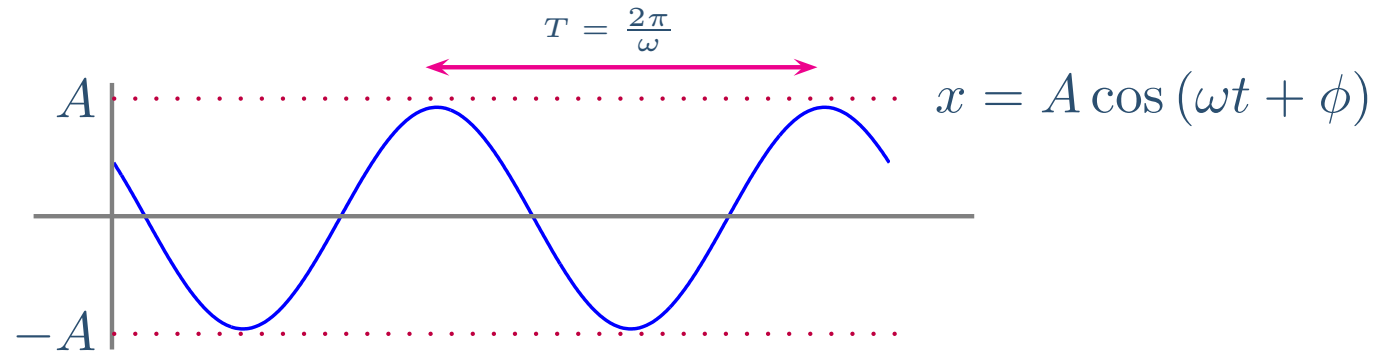
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Differential Equation for SHM: $\frac{d^2x}{dt^2} = -\left(\frac{k}{m}\right)x$

$$v = \frac{dx}{dt} = -\omega A \sin(\omega t + \phi)$$

General Solution

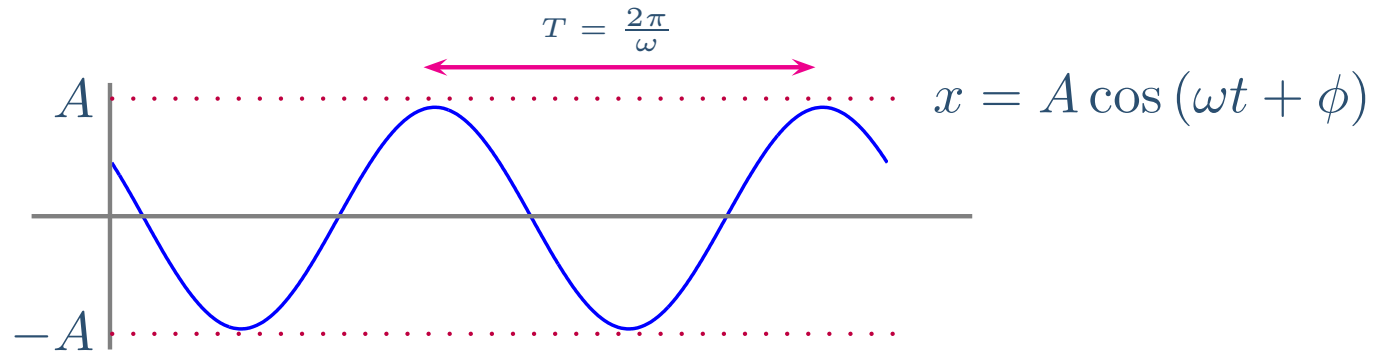


Differential Equation for SHM: $\frac{d^2x}{dt^2} = -\left(\frac{k}{m}\right)x$

$$v = \frac{dx}{dt} = -\omega A \sin(\omega t + \phi)$$

$$\frac{d^2x}{dt^2} = -\omega^2 A \cos(\omega t + \phi)$$

General Solution

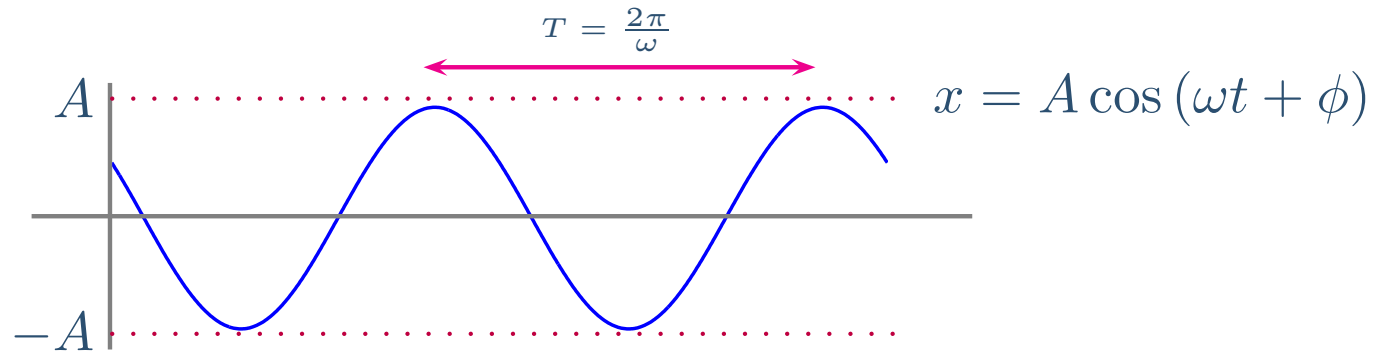


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General Solution



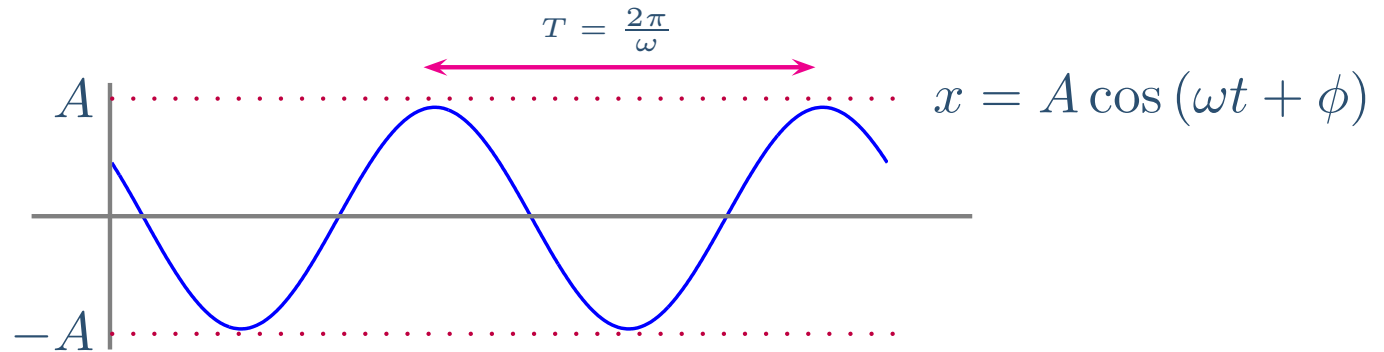
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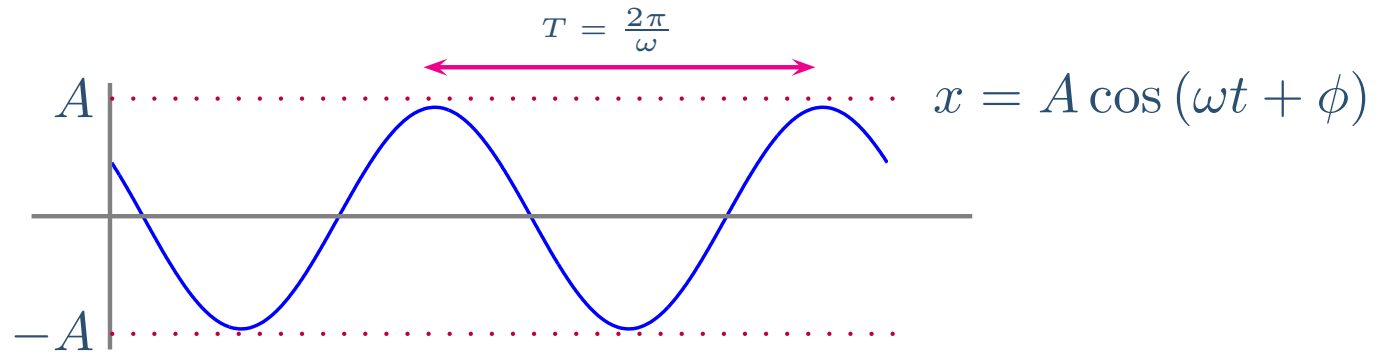
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General Solution



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$$\omega^2 = \left(\frac{k}{m}\right)$$

$$\omega = \sqrt{\frac{k}{m}}$$

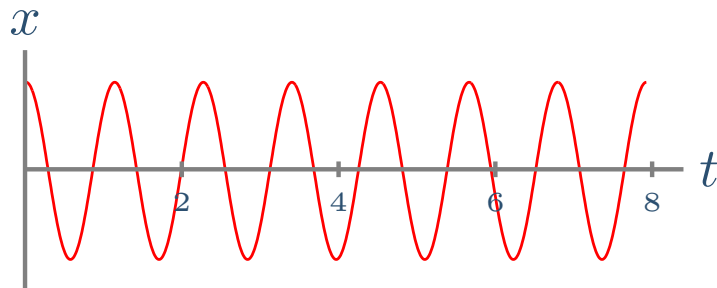
SHM Exercise

Three position-versus-time graphs are shown. Assuming the mass was the same for each, in which case was the spring constant largest?

SHM Exercise

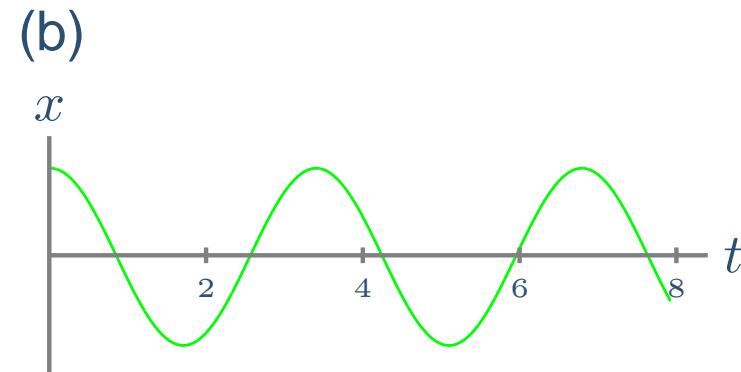
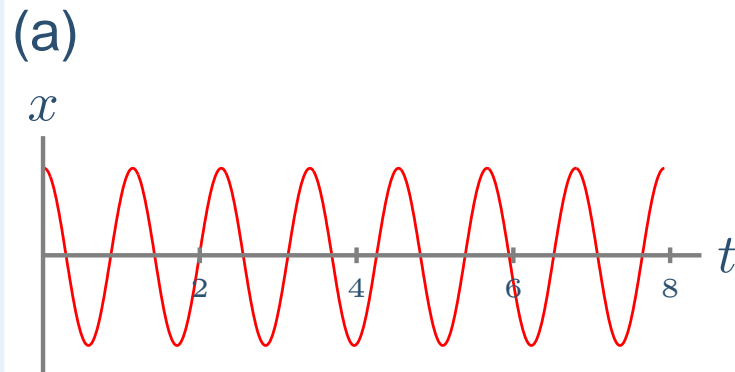
Three position-versus-time graphs are shown. Assuming the mass was the same for each, in which case was the spring constant largest?

(a)



SHM Exercise

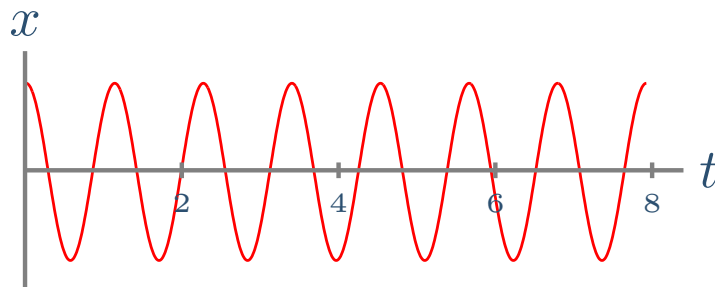
Three position-versus-time graphs are shown. Assuming the mass was the same for each, in which case was the spring constant largest?



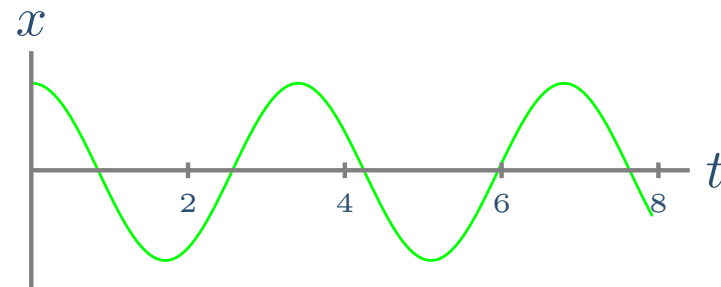
SHM Exercise

Three position-versus-time graphs are shown. Assuming the mass was the same for each, in which case was the spring constant largest?

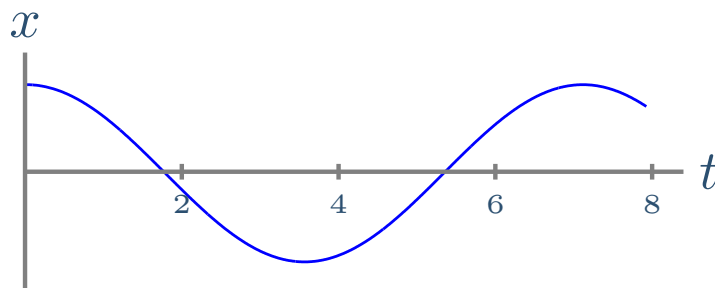
(a)



(b)

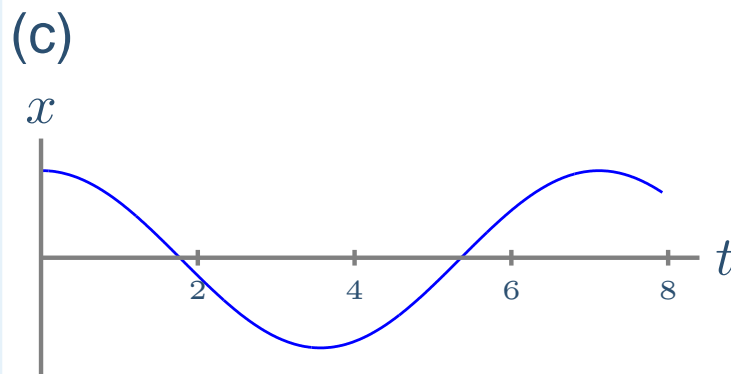
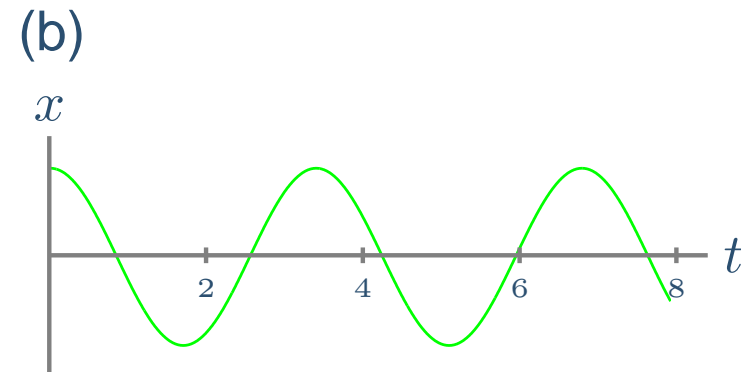
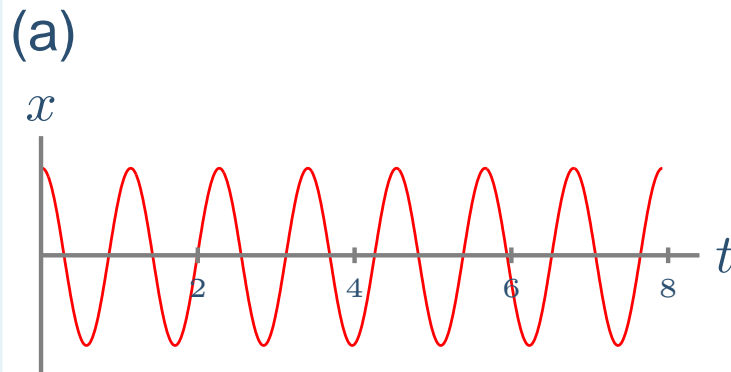


(c)



SHM Exercise

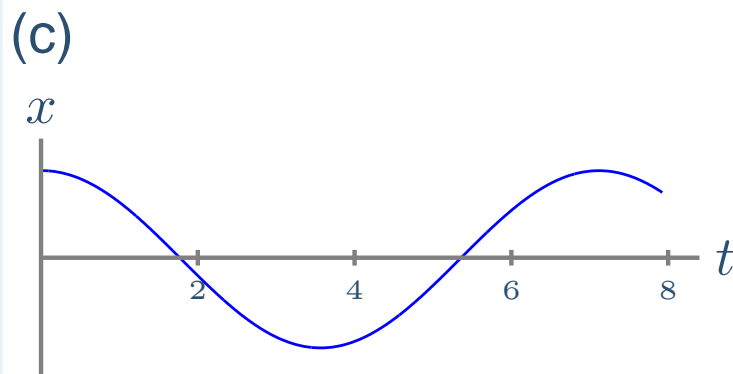
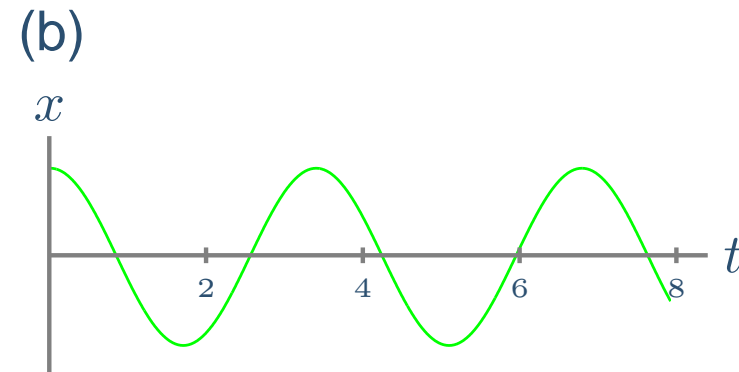
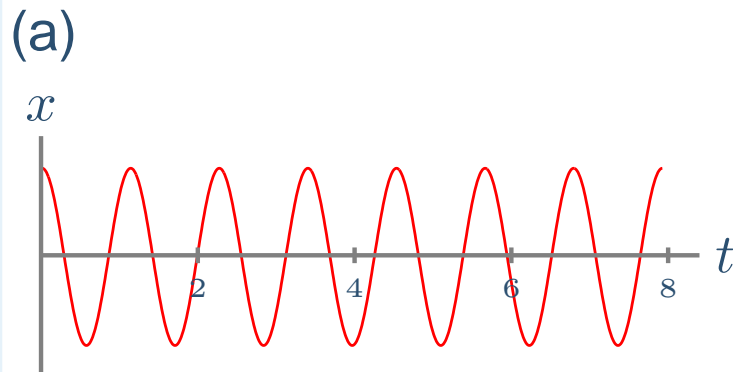
Three position-versus-time graphs are shown. Assuming the mass was the same for each, in which case was the spring constant largest?



(d) The spring constant is the same for each

SHM Exercise

Three position-versus-time graphs are shown. Assuming the mass was the same for each, in which case was the spring constant largest?

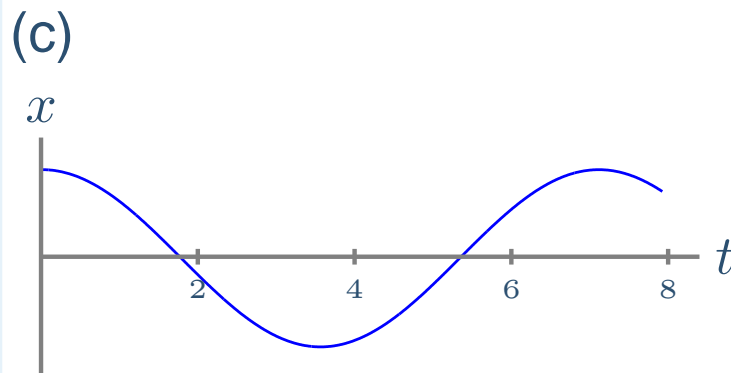
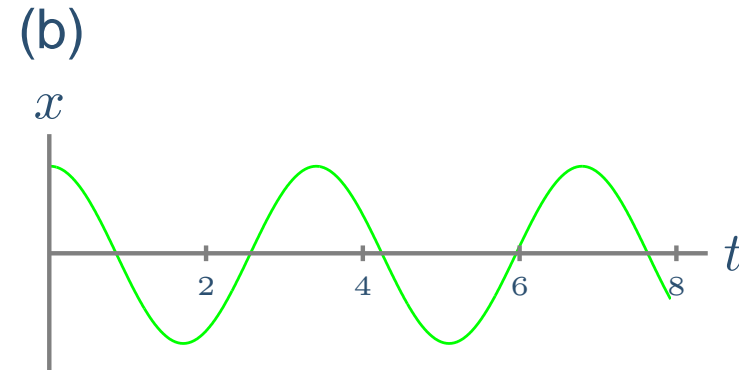
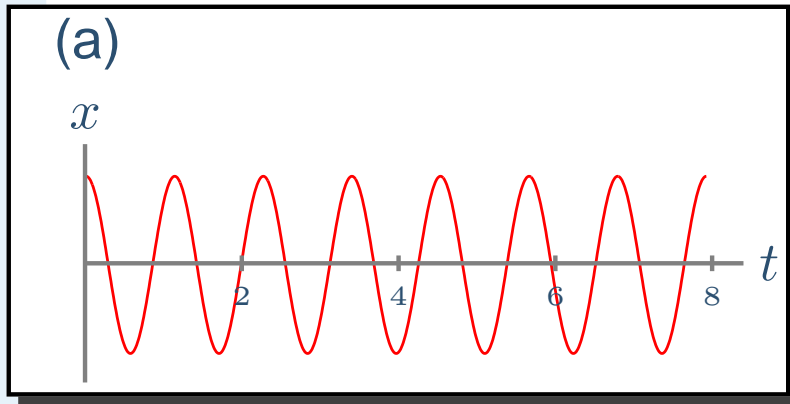


(d) The spring constant is the same for each

(e) There is not enough information to determine

SHM Exercise

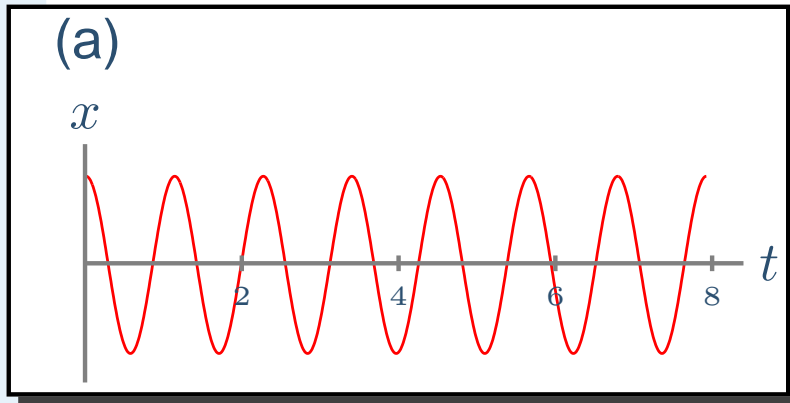
Three position-versus-time graphs are shown. Assuming the mass was the same for each, in which case was the spring constant largest?



- (d) The spring constant is the same for each
- (e) There is not enough information to determine

SHM Exercise

Three position-versus-time graphs are shown. Assuming the mass was the same for each, in which case was the spring constant largest?



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

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

So the largest spring constant would have the shortest period (and largest frequency)

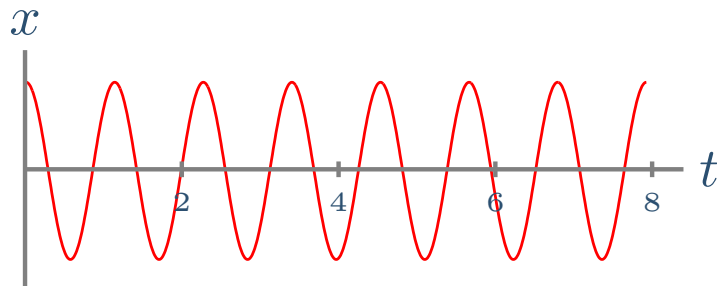
SHM Exercise II

Three position-versus-time graphs are shown. Assuming the spring constant was the same for each, in which case was the mass largest?

SHM Exercise II

Three position-versus-time graphs are shown. Assuming the spring constant was the same for each, in which case was the mass largest?

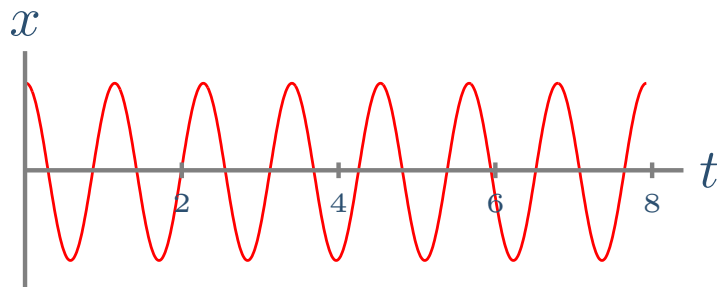
(a)



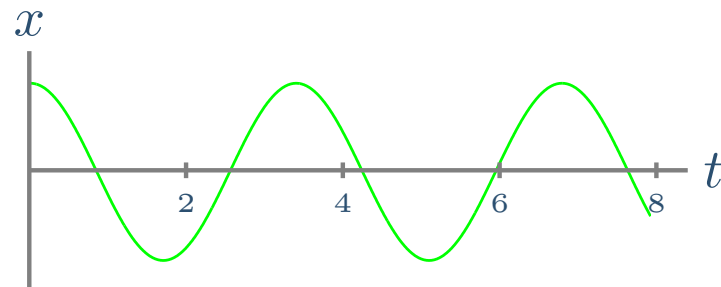
SHM Exercise II

Three position-versus-time graphs are shown. Assuming the spring constant was the same for each, in which case was the mass largest?

(a)

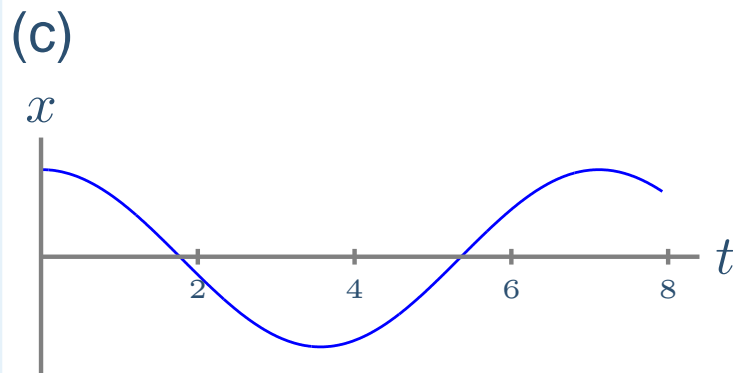
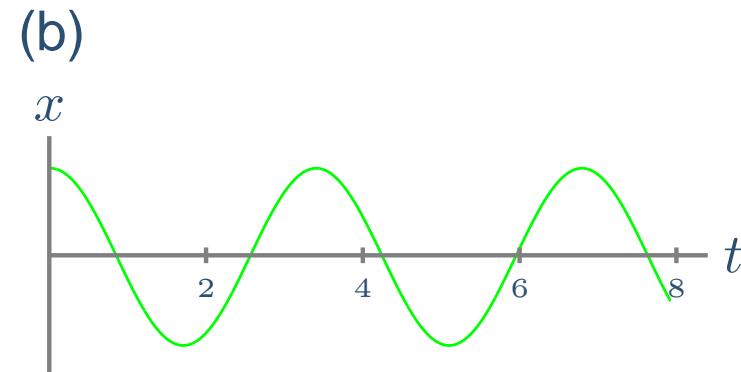
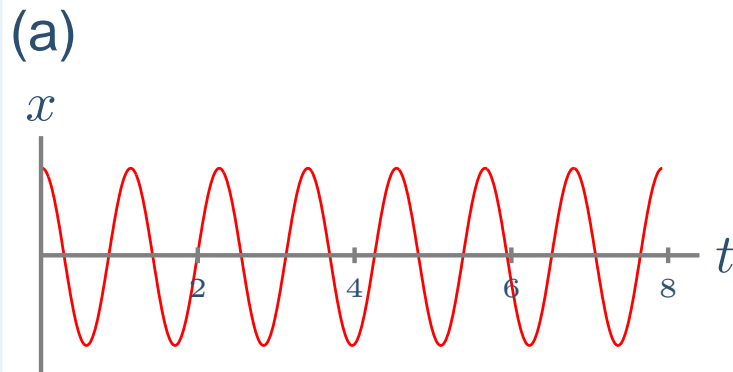


(b)



SHM Exercise II

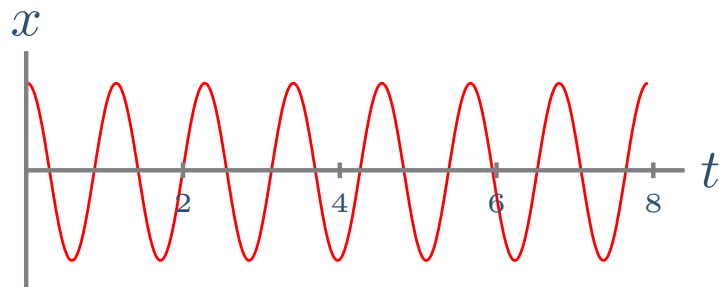
Three position-versus-time graphs are shown. Assuming the spring constant was the same for each, in which case was the mass largest?



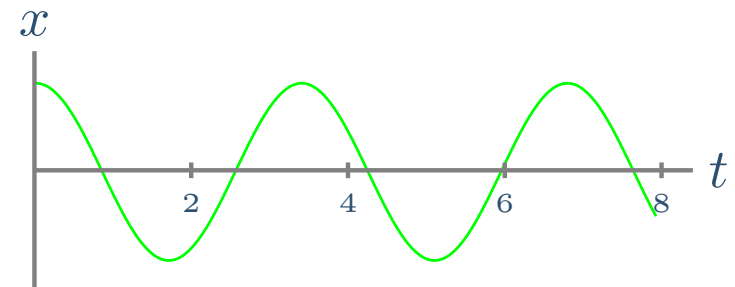
SHM Exercise II

Three position-versus-time graphs are shown. Assuming the spring constant was the same for each, in which case was the mass largest?

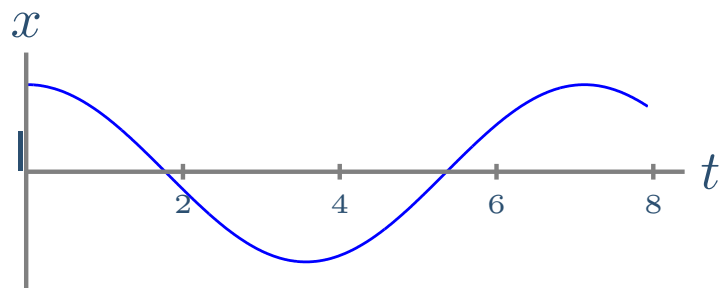
(a)



(b)



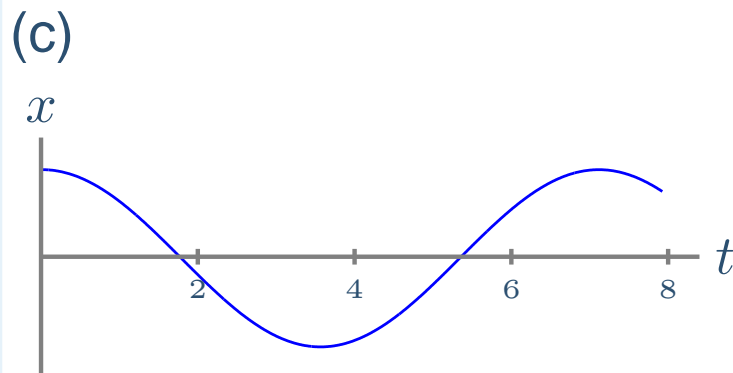
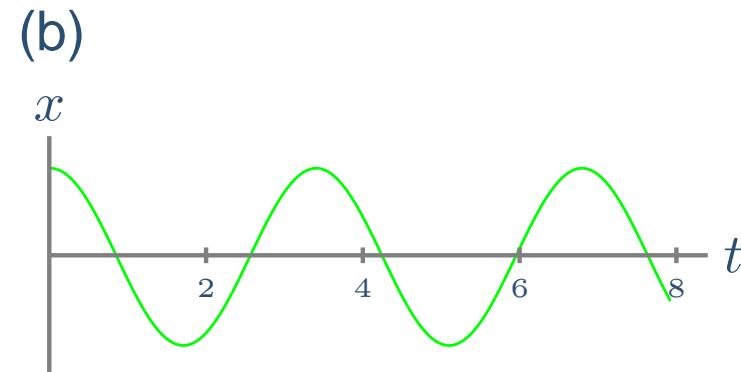
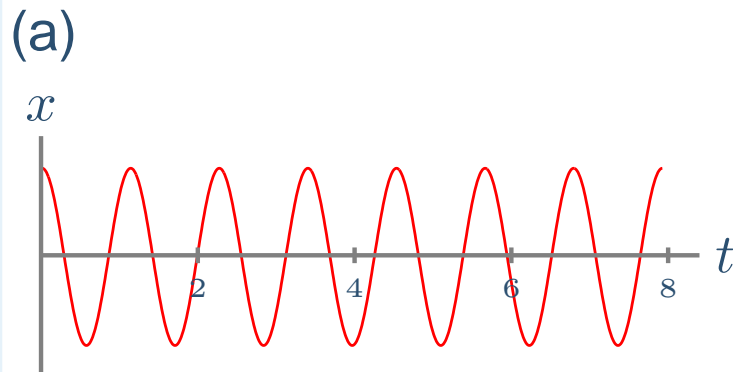
(c)



(d) The mass is the same for each

SHM Exercise II

Three position-versus-time graphs are shown. Assuming the spring constant was the same for each, in which case was the mass largest?

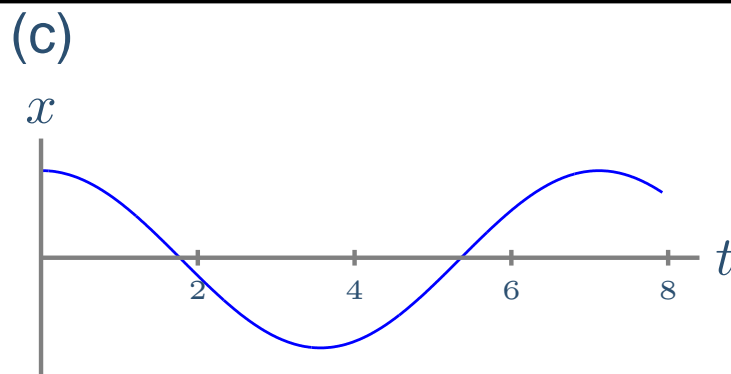
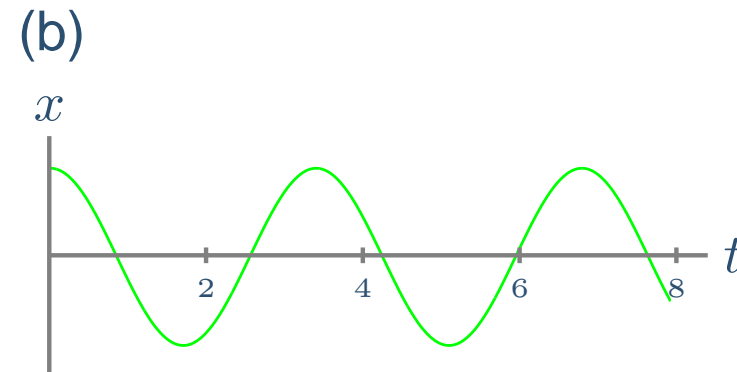
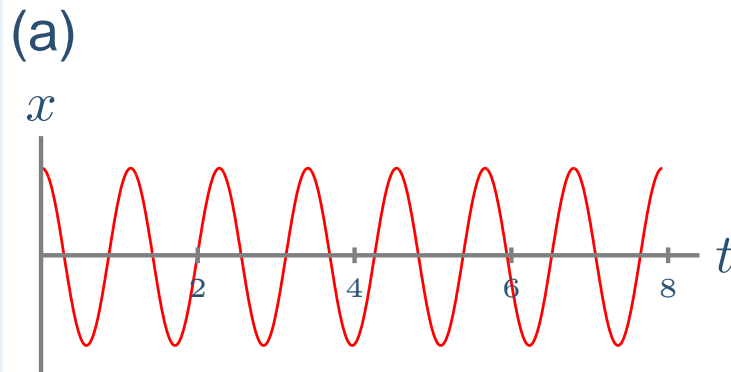


(d) The mass is the same for each

(e) There is not enough information to determine

SHM Exercise II

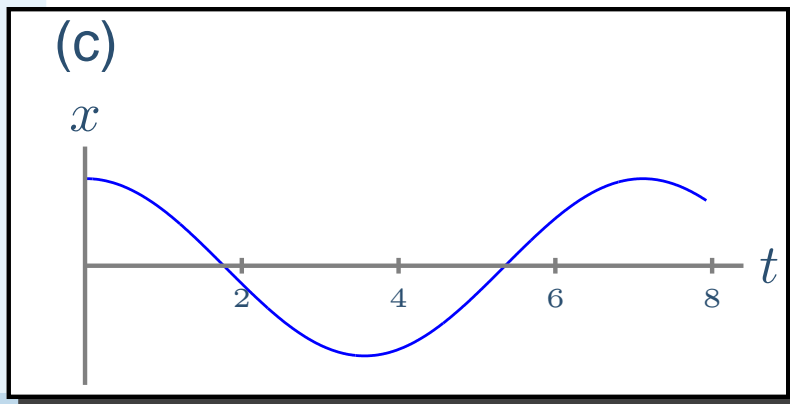
Three position-versus-time graphs are shown. Assuming the spring constant was the same for each, in which case was the mass largest?



- (d) The mass is the same for each
- (e) There is not enough information to determine

SHM Exercise II

Three position-versus-time graphs are shown. Assuming the spring constant was the same for each, in which case was the mass largest?



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

So the largest mass would have the longest period (and smallest frequency)