No labs today

Please, login into webassing, locate LectureMCQ_L18 (PY105) and answer question 1 (but ONLY Q1!).

Pleas sign in using the sign-in sheets on the bench.

Good morning!

Please, pick up YOUR exam,

Thank you

LectureMCQ_L18 Question 2 !

Please, asses your expectation regarding the exam

1. The Exam was much harder than I expected
2. The Exam was somewhat harder than I expected
3. The Exam was about as I expected
4. The Exam was somewhat easier than I expected
5. The Exam was much easier than I expected
6. The Exam was way too short.
7. When did we have it? Did I miss an exam?
8. I took PY211 exam by mistake, it was OK

Exam problems

similar →

Problems:

1. HW
2. Lectures
3. Units (IL)

Train yourself in recognition!

Practice HW
Practice exams

Some helpful questions for solving physics problems (page # 12)

1. What objects are involved? What processes are happening to them? (use your imagination - make a picture showing the objects and the processes they are involved into)
2. What properties of the objects and the processes might be important?
3. What physical quantities should be used for describing those properties, what connections might be important?
5. What laws or definitions should be used to describe important connections mathematically?
6. How can I solve my equations mathematically?
8. Does it make a sense?
9. Could I solve a similar problem again? How much time would it take? Who could help me (if I need it)?

http://teachology.xyz/general_algorithm.htm

New topics (do not read this slide)

SHM, stable equilibrium, restoring force, oscillations, small oscillations, Hooke's law, Newton's 2nd law for SHM, simple harmonic motion (SHM), SHM for horizontal spring, analogy between SHM and UCM, motion equation for SHM,S, V, A graphs for SHM, period, frequency, angular frequency, amplitude, elastic potential energy, energy graphs, conservation of energy, SHM for a vertical spring, a simple pendulum, SHM for a simple pendulum, a physical pendulum; fluids, density, pressure, pressure in a static fluid, atmospheric pressure, gauge pressure, absolute pressure, the Pascal's law, the buoyant force, Archimedes' principle, A static equilibrium for objects in liquid, solving buoyancy problems, fluid dynamics, an ideal fluid, streamline flow, an incompressible fluid, mass flow rate, volume flow rate, the continuity equation, the Bernoulli's equation, solving fluid dynamics problems.

HW3P1 recommended deadline = 6/22   11 pm
actual deadline = 6/28 11 pm

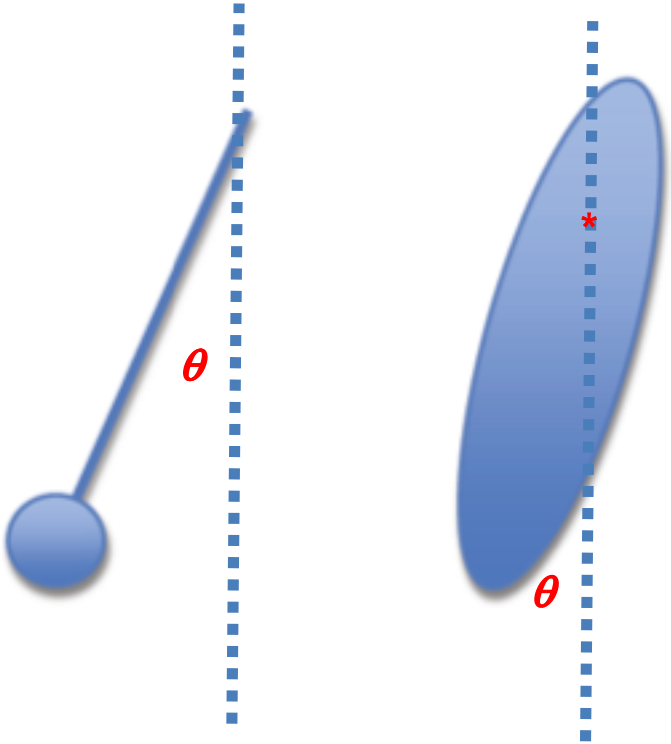
HW3P2 recommended deadline = 6/24   11 pm
actual deadline = 6/28 11 pm

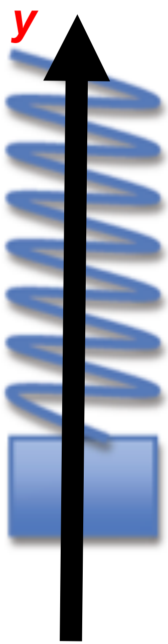
HW3P3 recommended deadline = 6/26   11 pm
actual deadline = 6/28 11 pm

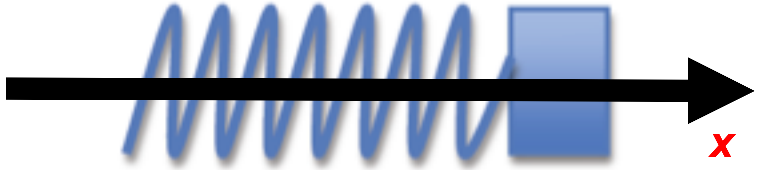
HW3P4 recommended deadline = 6/27   11 pm
actual deadline = 6/28 11 pm

Oscillations !!

When the motion repeats itself!



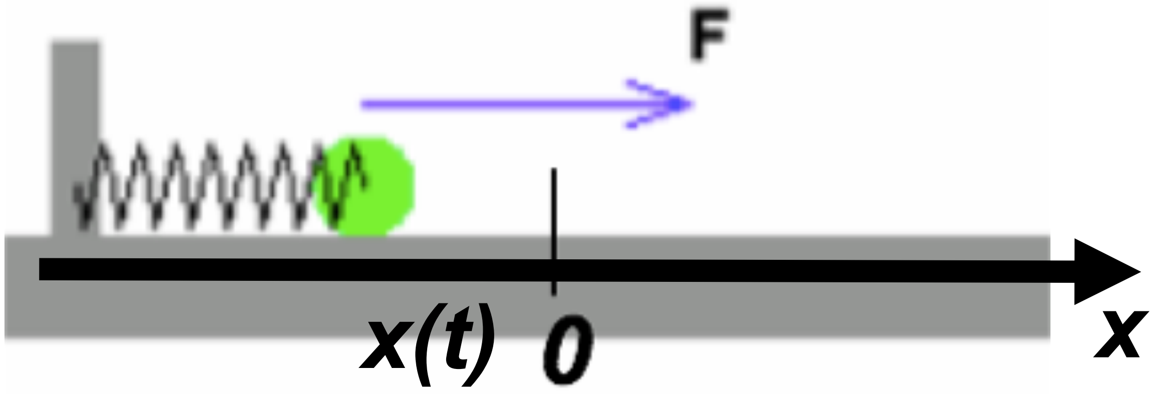




a.k.a. a ***stable*** equilibrium

Always choose the origin at the equilibrium position !!!!

Restoring force always points at the equilibrium position !!!!



Dynamics of SHM

Hooke's law;
setting the origin
at the equilibrium

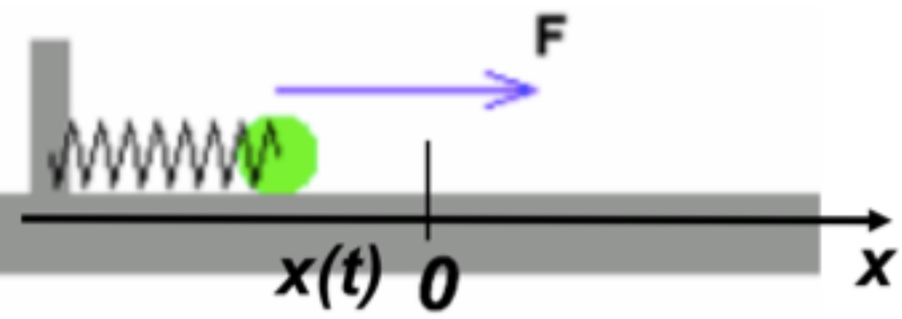
N2L

$ma_x = F_x$

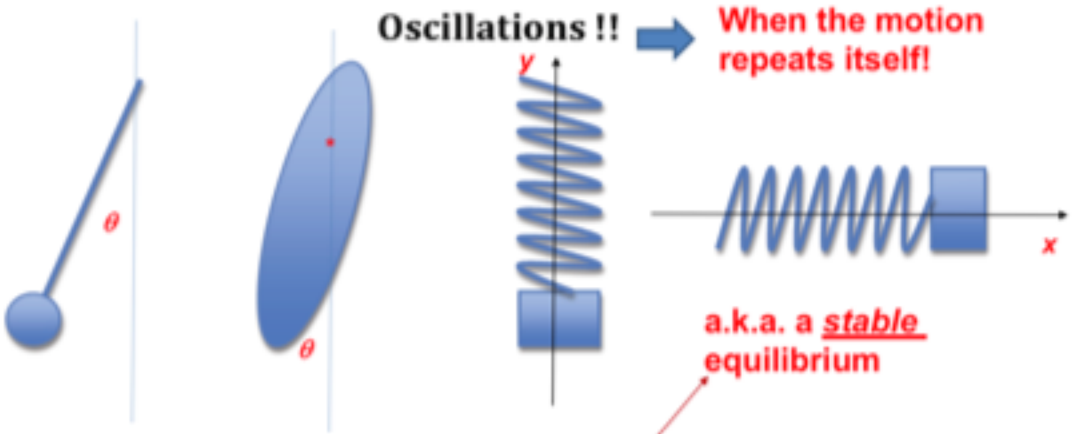
$F_x = -kx$

$ma_x = -kx$

$$a_x = -\frac{k}{m}x \qquad \boxed{\frac{k}{m} = \omega^2} \qquad \boxed{a_x = -\omega^2 x} \qquad \frac{a_x}{x} = -\omega^2$$



Dynamics of SHM



Always choose the origin at the equilibrium position !!!!

Restoring force always points at the equilibrium position !!!!

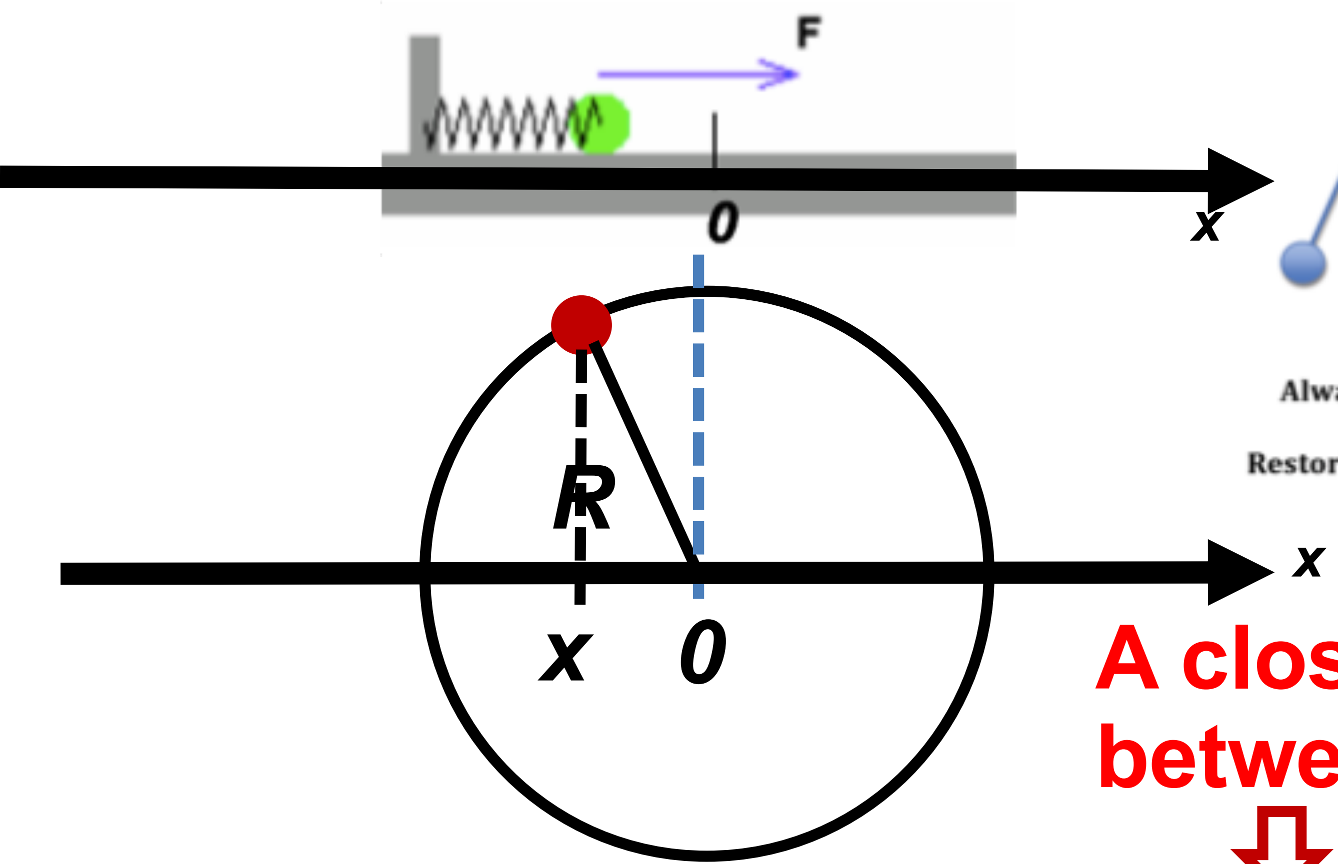
For an object on a spring

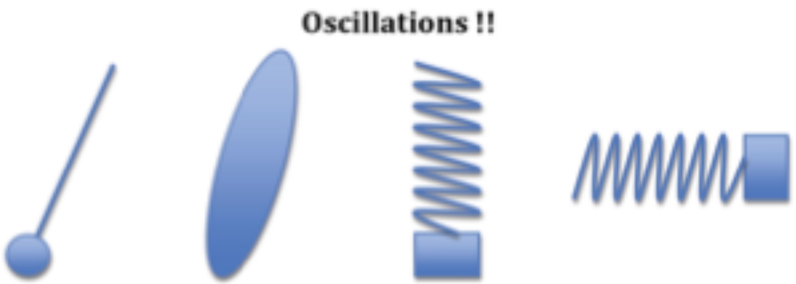
$$\boxed{\frac{k}{m} = \omega^2}$$

For ANY SHM

$$\boxed{a_x = -\omega^2 x}$$

Simple Harmonic Motion v. Rotational Motion





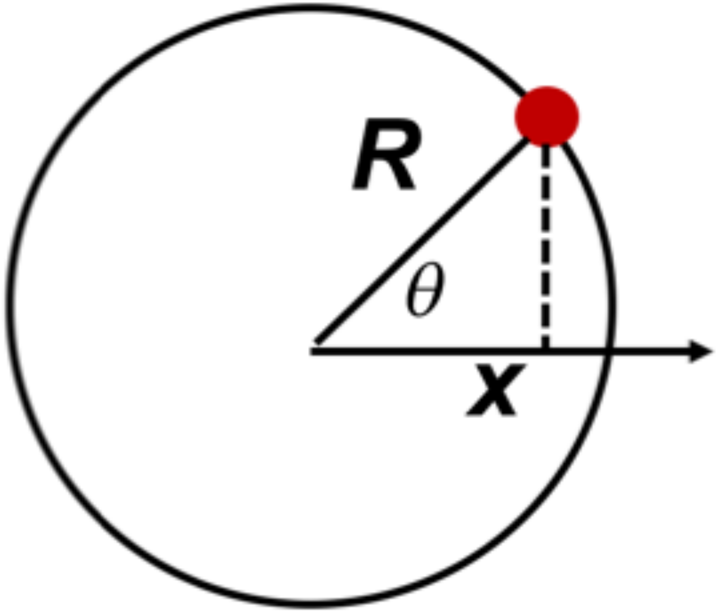
Always choose the origin at the equilibrium position !!!!

Restoring force always points at the equilibrium position !!!!

A close analogy between SHM and RM:

$\boxed{\textit{the same } x \textit{ - coordinate!}}$

SHM v. Rotational Motion



1. $x = R * \cos\theta$

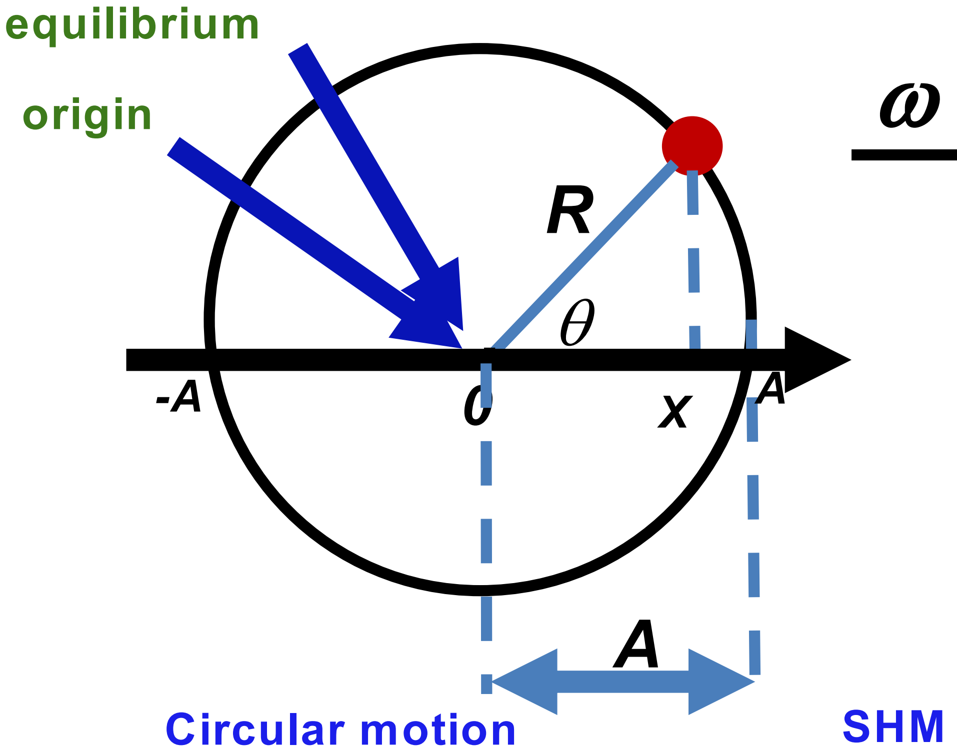
2. $\theta = \theta_0 + \omega t$

SHM equation

$$\boxed{x = R * \cos(\theta_0 + \omega t)}$$

SHM v. Rotational Motion

For rotational motion ← $R = A$ → For oscillations



$\underline{\omega = \text{const}}$

$\underline{\theta = \theta_0 + \omega t}$

$$\boxed{\omega = \frac{2\pi}{T} = 2\pi f}$$

$X = R\cos(\theta) = A\cos(\omega t + \theta_0)$ ⇦ "Our" motion equation

The blast from the …trigonometry

$\cos(35^0) = \underline{0.819}$

$-\cos(35^0 + \underline{180}) = \underline{0.819}$

$\sin(35^0 + \underline{90}) = \underline{0.819}$

The blast from the …trigonometry

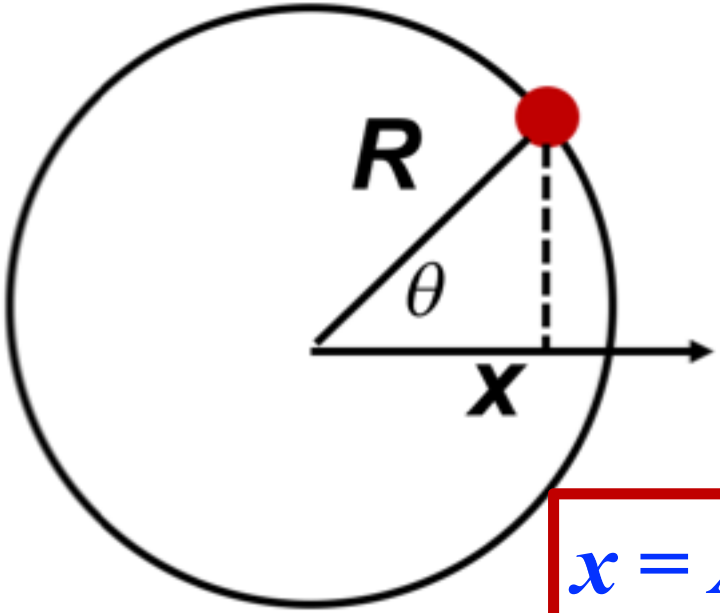
$$\cos(35^0) = 0.819 \qquad -\cos(35^0 + 180) = 0.819$$

$$\sin(35^0 + 90) = 0.819$$

$$\cos(\theta) = -\cos(\theta + 180^0) = \sin(\theta + 90^0)$$

cos, sin, -cos, -sin can be converted into each other!

SHM v. Rotational Motion



1. $x = A * \cos\theta$ 2. $\theta = \theta_0 + \omega t$

SHM equation

$$\boxed{x = A * \cos(\theta_0 + \omega t)}$$

or

We can ALWAYS *convert* cos into sin and back!

ALSO SHM equation $x = \pm A * \sin(\underline{\xi_0} + \omega t)$

http://math2.org/math/algebra/functions/sincos/properties.htm

A *general* motion equation *x*(*t*) for a SHM

$$x(t) = [number] * \{\sin or \cos\}([number] * t + [number]) + [number]$$

An order may differ due to : A + B = B + A and AB = BA

examples

$$x(t) = 3cos(2t)$$

$$x(t) = 3cos(5t)$$

$$x(t) = 3cos(-5t)$$

$$x(t) = -3cos(2t)$$

$$x(t) = -3cos(2 - 5t)$$

$$x(t) = -3sin(2 - 5t)$$

$$x(t) = 3sin(2t)$$

$$x(t) = -3cos(-5t + 2) + 1.23456$$

$$x(t) = -3sin(2t)$$

$$x(t) = -1.23456 + \left(\frac{1}{3}\right) sin(-0.5 + 7.7t)$$

Webassign: L18 Q3

How many equations from the equations below do NOT describe SHM?

1. $x(t) = 3cos(2t)$
2. $x(t) = 3cos(5t)$
3. $x(t) = -3cos(2t)$
4. $x(t) = -3(2 - 5t)$
5. $x(t) = -3cos(-5t + 2) + 1.23456$
6. $x(t) = 3tan(2t)$
7. $x(t) = -1.23456 + \left(\frac{1}{3}\right) sin(-0.5 + 7.7t)$

$$x(t) = [number] * \{\sin or\ cos\}([number] * t + [number]) + [number]$$

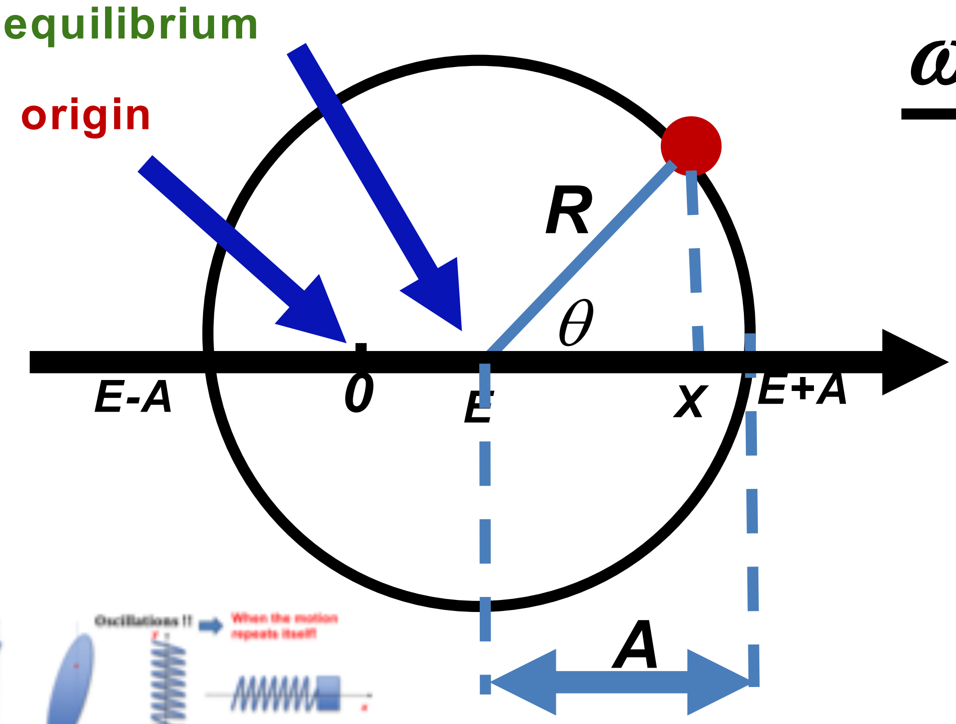
How many equations from the equations below do NOT describe SHM?

=> 2

1. $x(t) = 3cos(2t)$
2. $x(t) = 3cos(5t)$
3. $x(t) = -3cos(2t)$
4. $x(t) = -3(2 - 5t)$
5. $x(t) = -3cos(-5t + 2) + 1.23456$
6. $x(t) = 3tan(2t)$
7. $x(t) = -1.23456 + \left(\frac{1}{3}\right) sin(-0.5 + 7.7t)$

SHM v Rotational Motion: *in general*

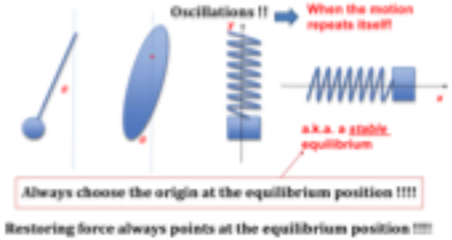
For rotational motion ← $R = A$ → For oscillations



$$\underline{\omega = \text{const}}$$

$$\underline{\theta = \theta_0 + \omega t}$$

$$\boxed{\omega = \frac{2\pi}{T} = 2\pi f}$$



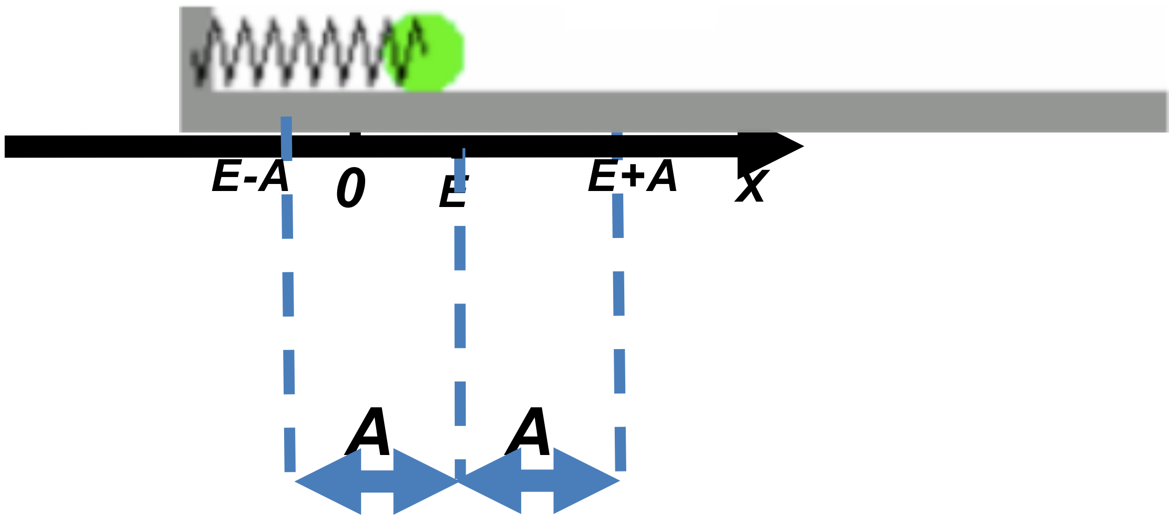
$$X = R\cos(\theta) + E = \underline{A\cos(\omega t + \theta_0) + E}$$

SHM v Rotational Motion: *in general*

A = the maximum displacement from the equilibrium

$\omega = \text{const}$

$\theta = \theta_0 + \omega t$



$$\boxed{\omega = \frac{2\pi}{T} = 2\pi f}$$

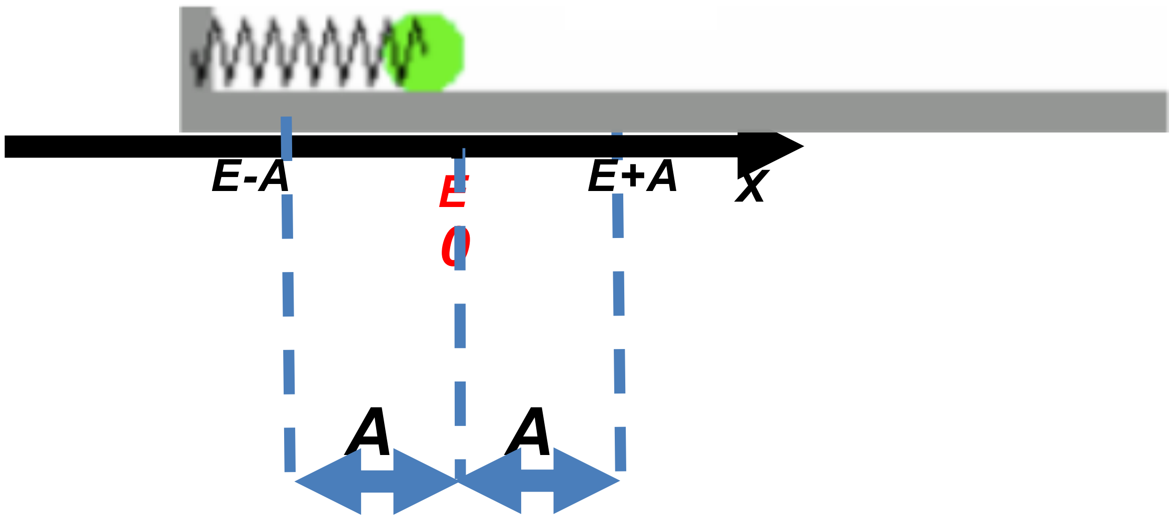
$$\boxed{X = A\cos(\omega t + \theta_0) + E}$$

SHM v Rotational Motion: *if E = 0*

A = the maximum displacement from the equilibrium

$$\omega = \text{const}$$

$$\theta = \theta_0 + \omega t$$



$$\boxed{\omega = \frac{2\pi}{T} = 2\pi f}$$

$$\boxed{X = A\cos(\omega t + \theta_0)}$$

$x(t)=A\cos(\omega t+\theta_0)+E$ the summary of kinematics of SHM

A is the amplitude, which is the magnitude of the *maximum* displacement from the equilibrium position.

$T = t/N = 1/f = 2\pi/\omega$ is a period, which is the time for one complete oscillation (one complete oscillation has four similar parts)

$f = N/t = 1/T$ is the frequency, i.e. the number of oscillations per one second.

$\omega = 2\pi f = 2\pi/T$ is an angular frequency, which is the number of oscillations per 2π seconds.

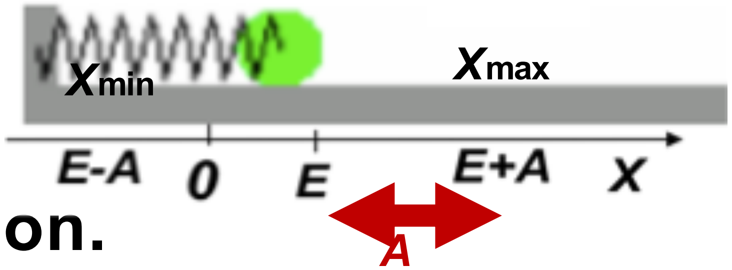
$\omega t + \theta_0$ is a phase; θ_0 is an initial phase (no need to bother with it)

E is the coordinate of the position between X_{max} and X_{min}

$x(t) = A\cos(\omega t + \theta_0) + E$

For an object on a spring

$$\frac{k}{m} = \omega^2$$



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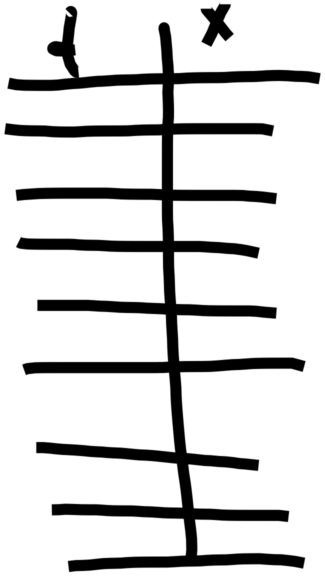
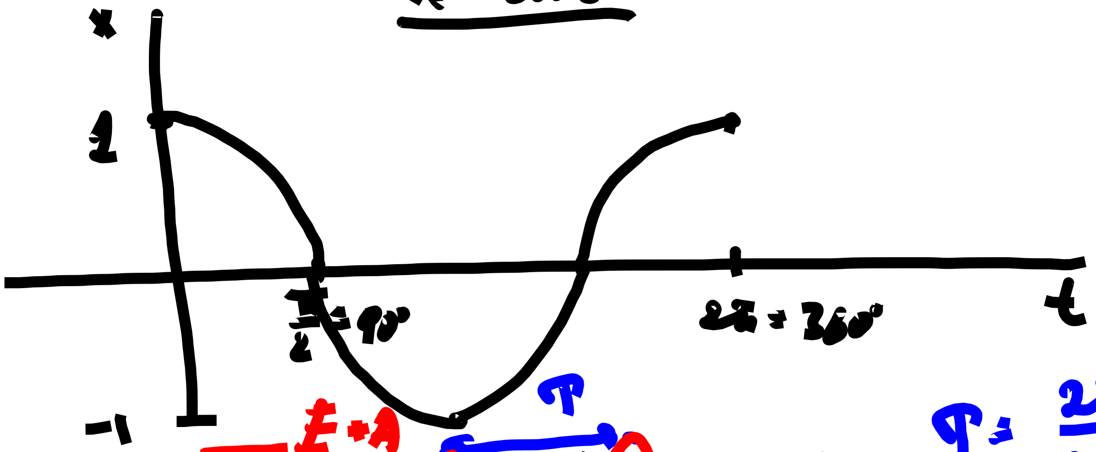
E is the coordinate of the position between X_{max} and X_{min}

SHM in general: a motion equation and a graph

$$x(t) = A\cos(\omega t + \theta_0) + E$$

$x = \cos t$





$x = A\cos(\omega t + \theta_0) + E$

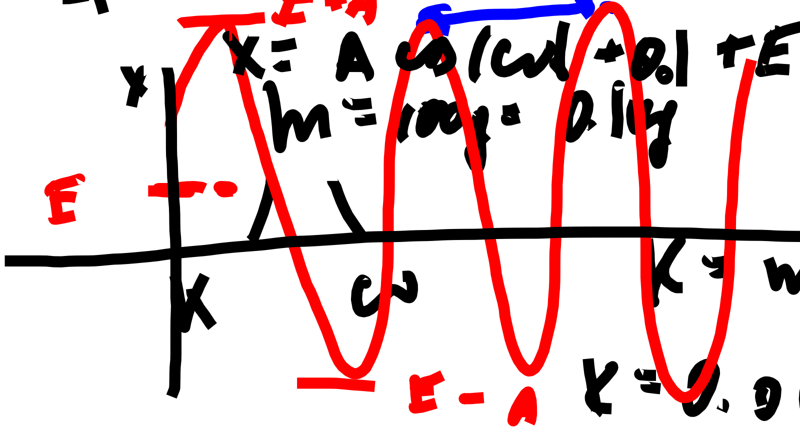
$m = 100g = 0.1kg$

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

$\omega^2 = \frac{K}{m}$

$K = m \cdot \omega^2 = 0.1 \cdot \left(\frac{\pi}{4}\right)^2 = \frac{0.1 \cdot \pi^2}{16} \frac{N}{m}$

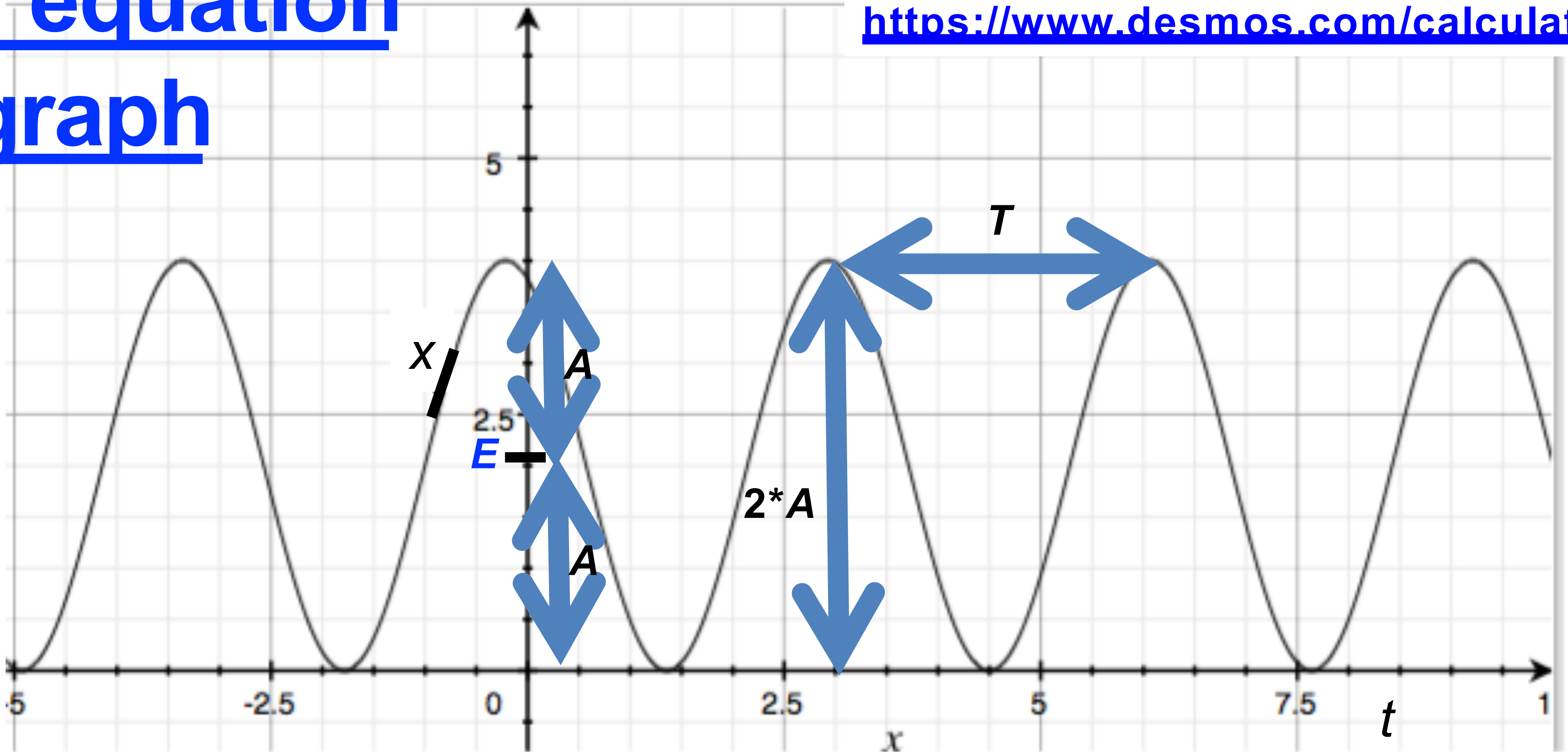
$K = 0.06 \frac{N}{m}$



SHM in general: a motion equation and a graph

$$x(t) = A\cos(\omega t + \theta_0) + E$$

https://www.desmos.com/calculator

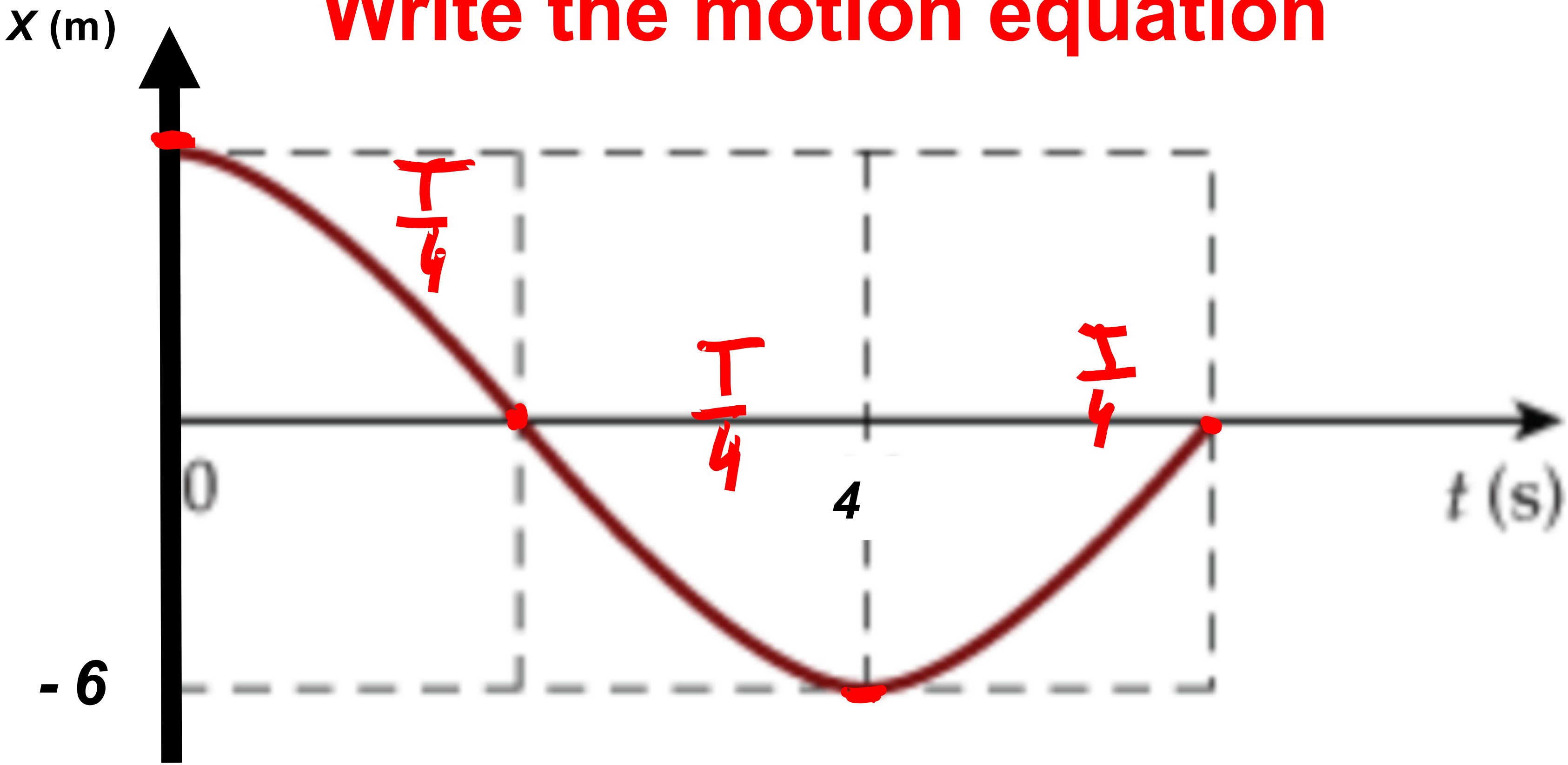


$$n = f = \nu = \frac{N}{t} = \frac{1}{T}$$

$$T = \frac{t}{N}$$

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

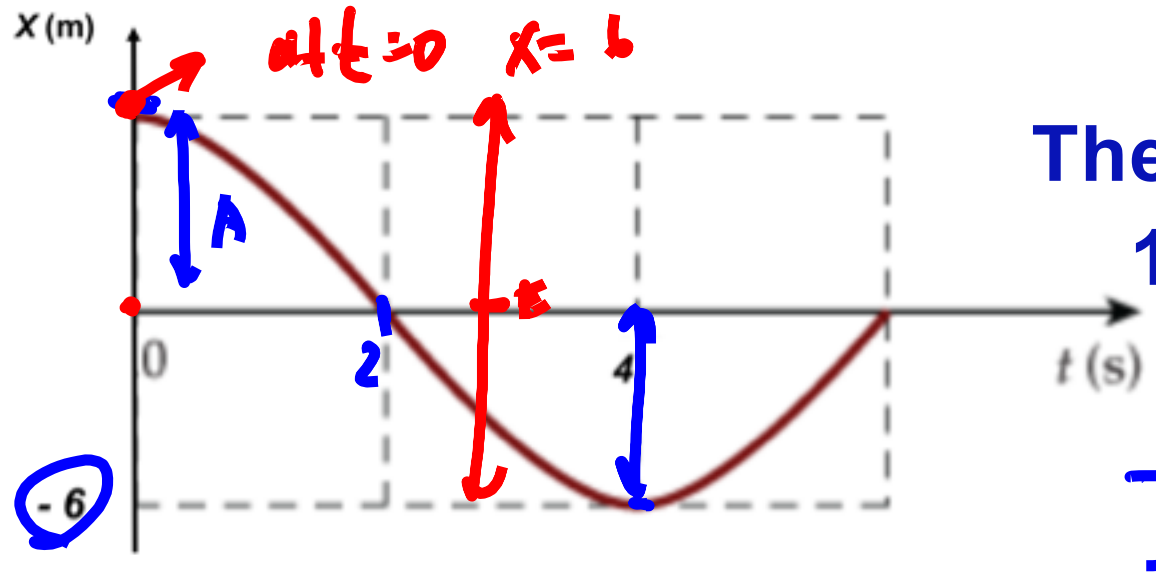
Write the motion equation



Webassign: L18 Q4

The period of this motion is

1. 1 s   2. 2 s   3. 3 s   4. 4 s   …



Webassign: L18 Q4

The period of this motion is

1. 1 s 2. 2 s 3. 3 s ...

$\frac{T}{4} = 2s \Rightarrow T = 8s$

$A = 6$

$\omega = \frac{2\pi}{T} = \frac{\pi}{4} \frac{rad}{s}$

$X = A\cdot\cos(\omega t + \theta_0) + \cancel{E}$

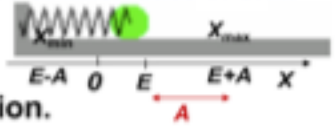
$X = 6\cdot\cos(\frac{\pi}{4}\cdot t + \theta_0)$; $6 = 6\cos(\frac{\pi}{4}0 + \theta_0)$

$1 = \cos\theta_0$, $\theta_0 = 0$

$x = 6\cos\frac{\pi}{4}t$

$x(t)=A\cos(\omega t+\theta_0)+E$ the summary of kinematics of SHM

A is the amplitude, which is the magnitude of the *maximum* displacement from the equilibrium position. $\frac{k}{m} = \omega^2$



$T = t/N = 1/f = 2\pi/\omega$ is a period, which is the time for one complete oscillation (one complete oscillation has four similar parts)

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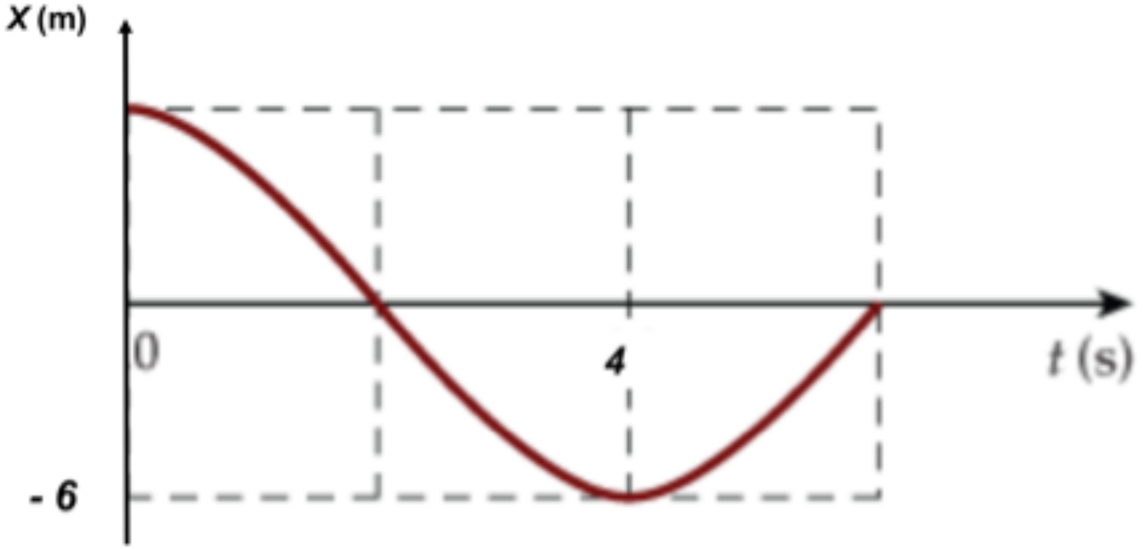
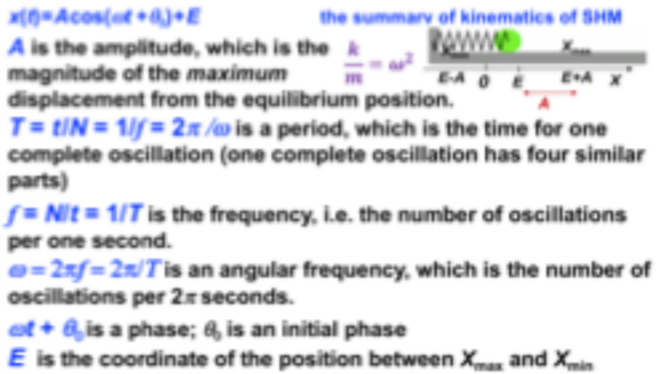
$\omega t + \theta_0$ is a phase; θ_0 is an initial phase

E is the coordinate of the position between X_{max} and X_{min}



This graph represents the motion of a a 100 g weight attached to a spring.

Calculate the spring/force constant of the spring.



$x(t) = A\cos(\omega t + \theta_0) + E$ the summary of kinematics of SHM

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E is the coordinate of the position between X_{max} and X_{min}

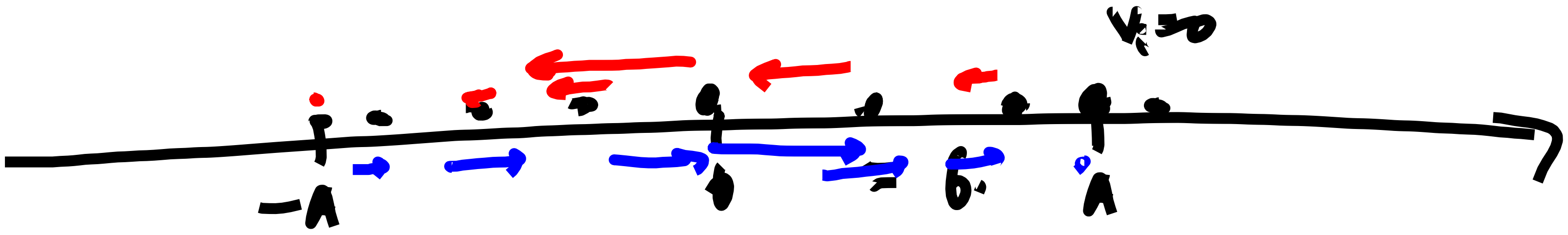
Special case:

1. $X_{equilibrium} = 0$ ($E = 0$)
2. Released from rest
3. $X_0 = A > 0$

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

At $t = 0$

THE MOTION DIAGRAM



Special case:

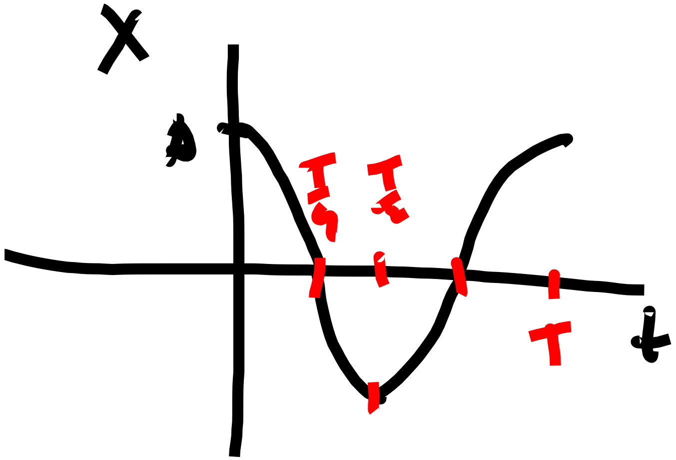
$$x(t) = A\cos(\omega t)$$

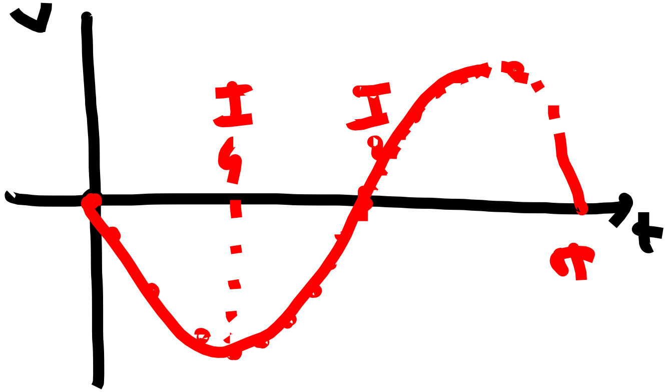
1. $X_{equilibrium} = 0$ ($E = 0$)
2. Released from rest
3. $X_0 = A > 0$

At $t = 0$

GRAPHS $x(t)$, $v(t)$

$V = -V_{max} \sin(\omega t)$





Special case:

1. $X_{equilibrium} = 0$ ($E = 0$)
2. Released from rest
3. $X_0 = A > 0$

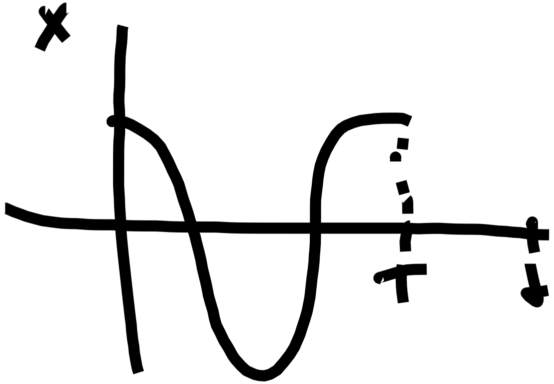
$$x(t) = A\cos(\omega t)$$

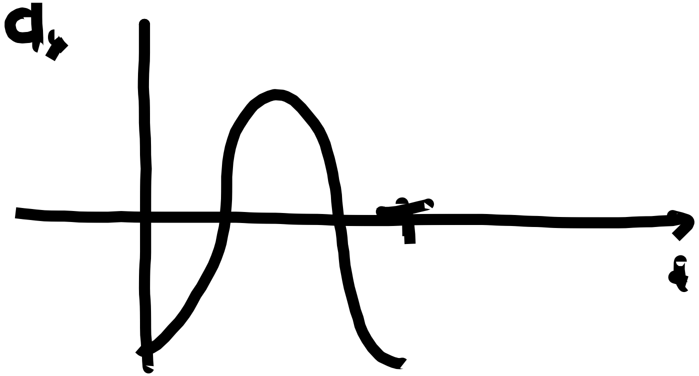
At $t = 0$

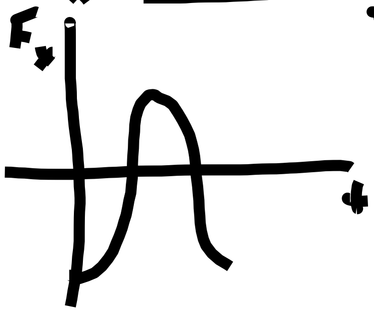
GRAPHS $x(t)$, $a(t)$

$a_x = -\omega^2 x$

$F_x = \underline{m \cdot a_x} = \underline{-kx}$

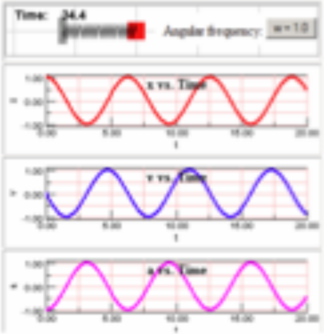






Graphs of position, velocity, and acceleration

In SHM (simple harmonic motion), the general equations for position, velocity, and acceleration are:



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

$$v(t) = -A\omega\sin(\omega t\ \ )$$

$$a_x = -\omega^2 x \qquad a(t) = -A\omega^2\cos(\omega t\ \ )$$

The phase angle θ_o is determined by the initial position and initial velocity.

The angular frequency for an object of mass m oscillating on a spring of spring constant k the angular frequency is given by:

$$\boxed{\omega^2 = \frac{k}{m}}$$

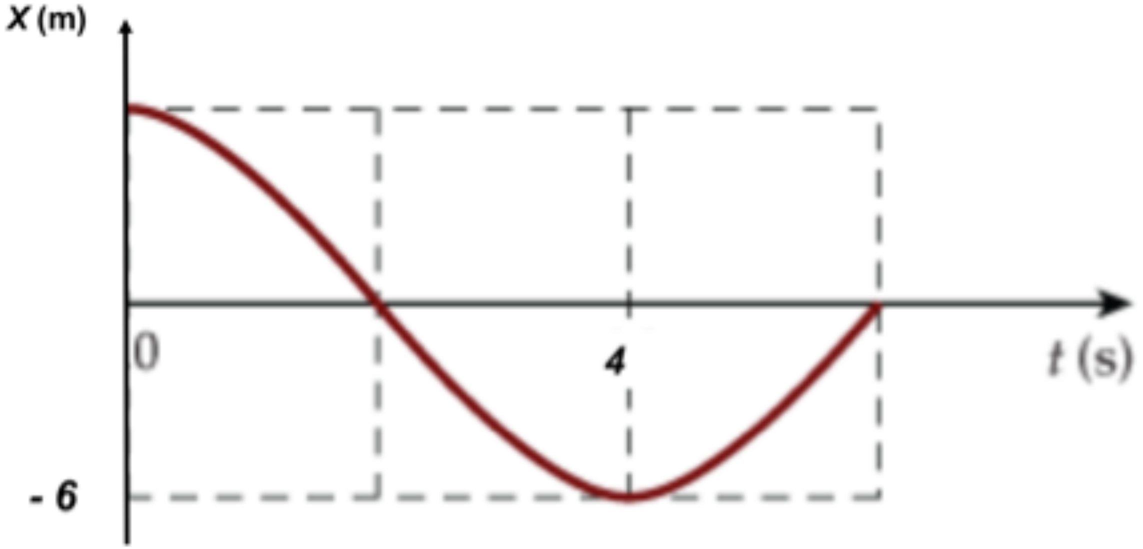
The most important connection

Whatever is multiplying the sine or cosine represents the maximum value of the quantity.

Thus: $x_{max} = A$ $\quad v_{max} = A\omega$ $\quad a_{max} = A\omega^2$ $\quad a_x = -\omega^2 x$

A special case (summary):

A cart is attached to a spring, we move a cart to the *right* from (E=0) equilibrium and release it from *rest*.

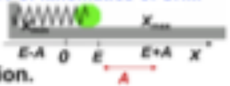


This graph represents the motion of a a 100 g weight attached to a spring.

Calculate v_{max} and a_{max}

$x(t) = A\cos(\omega t + \theta_0) + E$ the summary of kinematics of SHM

A is the amplitude, which is the magnitude of the *maximum* displacement from the equilibrium position. $\frac{k}{m} = \omega^2$



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$f = N/t = 1/T$ is the frequency, i.e. the number of oscillations per one second.

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$\omega t + \theta_0$ is a phase; θ_0 is an initial phase

E is the coordinate of the position between X_{max} and X_{min}

$a_x = -\omega^2 \cdot x$

$a_{max} = |-\omega^2 \cdot A| = A \cdot \omega^2 =$

$= 6 \cdot \left(\frac{\pi}{4}\right)^2$ m/s²

$V_m = \omega \cdot A = \frac{\pi}{4} \cdot 6$ m/s

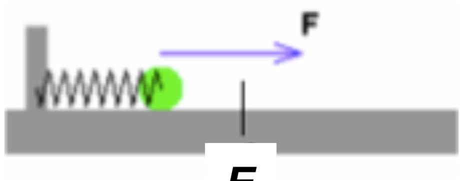
Graphs of position, velocity, and acceleration

In SHM (simple harmonic motion), the general equations for position, velocity, and acceleration are:

$\Delta x = x - E$ $\qquad x(t) = A\cos(\omega t + \theta_o) + E$

$F_x = -k\Delta x$ $\qquad v(t) = -A\omega\sin(\omega t + \theta_o)$

$a_x = -\omega^2 \Delta x$ $\qquad a(t) = -A\omega^2\cos(\omega t + \theta_o)$



The phase angle θ_o is determined by the initial position and initial velocity.

$$\boxed{X_{\text{equilibrium}} \neq 0 \;\; (E \neq 0)}$$

$$\boxed{\omega = \frac{2\pi}{T} = 2\pi f}$$

$$\frac{k}{m} = \omega^2$$

In general:

A cart is attached to a spring, we move a cart away from equilibrium and release it with a *push*.

Whatever is multiplying the sine or cosine represents the maximum value of the quantity.

Thus: $\quad x_{max} = A \qquad v_{max} = A\omega \qquad a_{max} = A\omega^2$

The motion equation of an object is

$$x(t) = -5\sin(3\pi t - 1) + 2$$ (*assume SI units*)

$$X = A\cos(\omega t + \theta_0) + E$$

Webassign: L18 Q5

The angular frequency equals (in rad/s)…

1. 1π
2. 2π
3. 3π
4. 4π
5. 5π
6. 6π
7. 7π
8. none of the above

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

The motion equation of an object is

$$x(t) = -5\sin(3\pi t + 1) + 2$$

Webassign: L18 Q5

$$X = A\cos(\omega t + \theta_0) + E$$

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

The angular frequency equals (in rad/s)…

1. 1π
2. 2π
3. 3π
4. 4π
5. 5π
6. 6π
7. 7π
8. none of the above

$A = |-5| = 5$

$\omega = 3\pi \ \frac{rad}{s}$

$f = \frac{1}{T} = \frac{3}{2} = 1.5 \ \frac{1}{s} = 1.5 \ s^{-1} = 1.5 \ Hz$

$T = \frac{2\pi}{\omega} = \frac{2\pi}{3\pi} = \frac{2}{3} s$

$a_{max} = \omega^2 A = (3\pi)^2 5$; $v_{max} = \omega A = 3\pi \cdot 5$

Also find: A, f, ω, v_{max}, a_{max}

The motion equation of an object is

$$x(t) = -5\sin(3\pi t - 1) + 2$$

ω = 3π rad/s

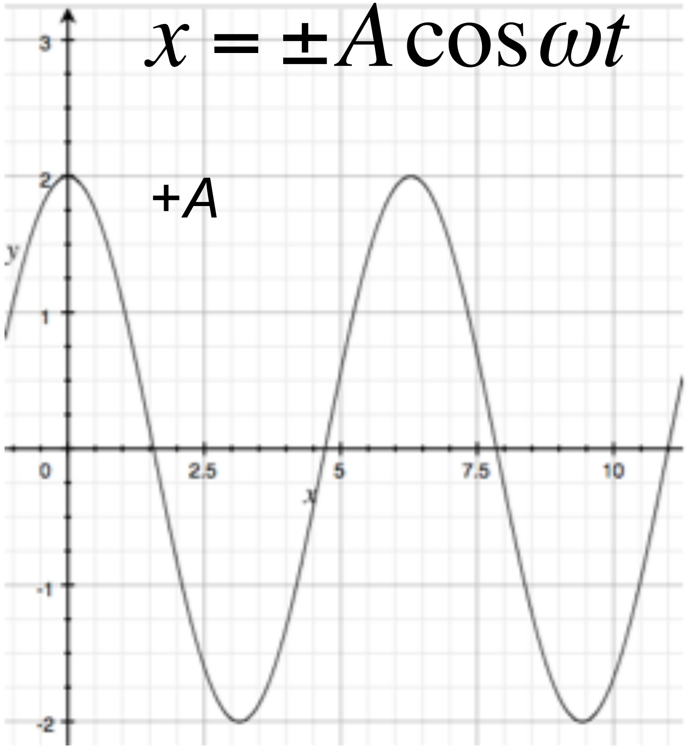
(*__assume SI units__*)

The period equals (s)…

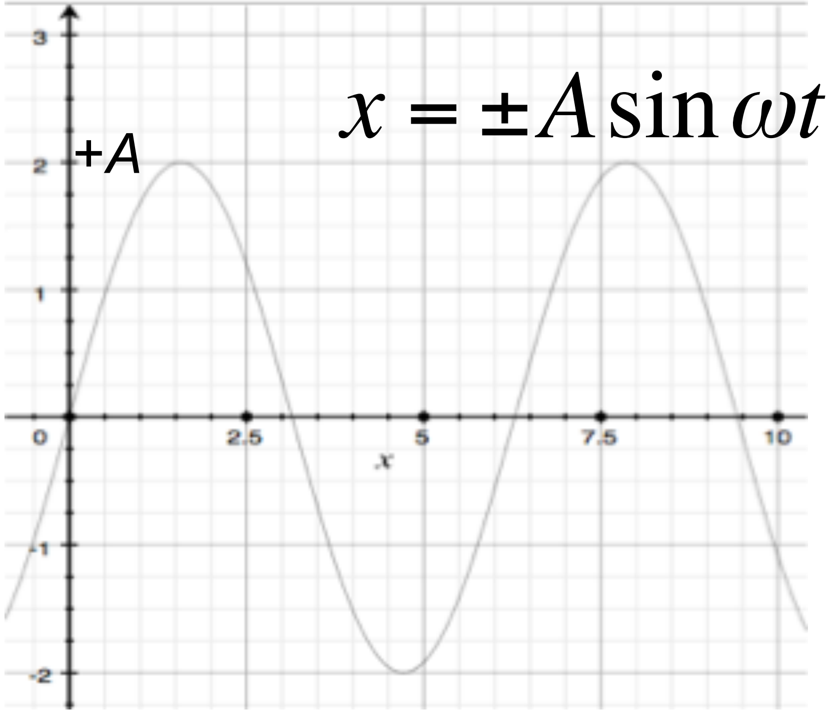
1. ~~1/3~~
2. 2/3
3. ~~3/3~~
4. ~~4/3~~

special cases

Released from rest:



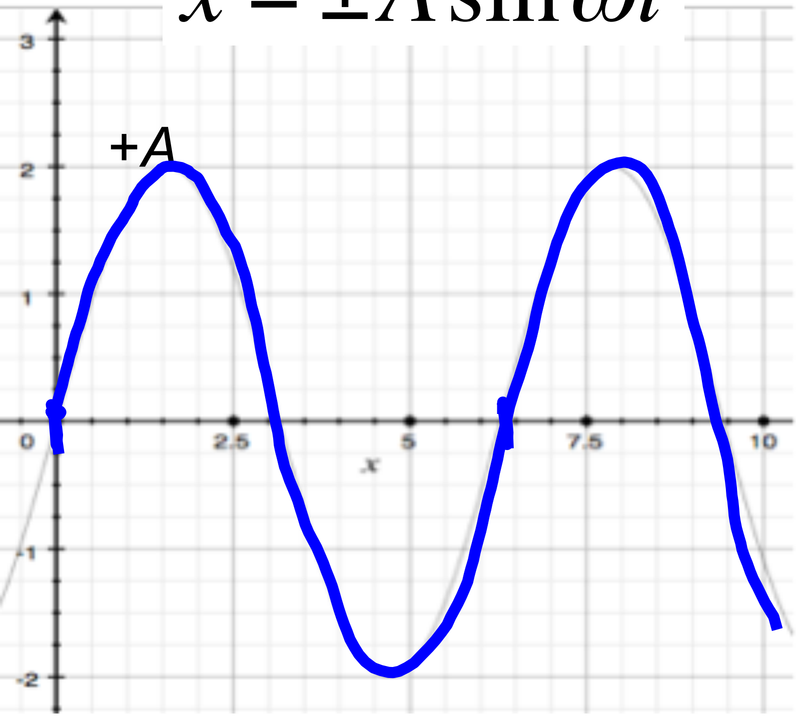
"Kicked" from equilibrium position:



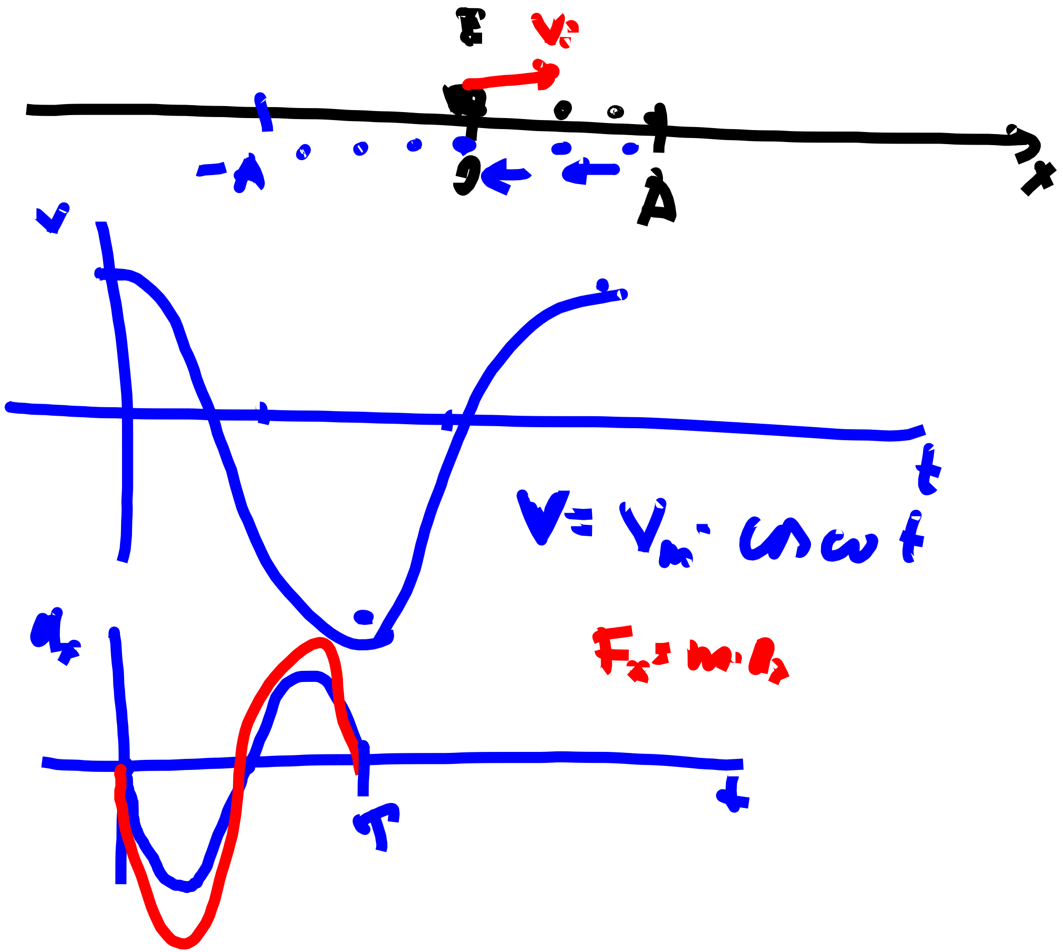
2ND special case

"Kicked" from equilibrium position: *v*(*t*), *a*(*t*)

$$x = \pm A \sin \omega t$$



$a_x = -\omega^2 x$



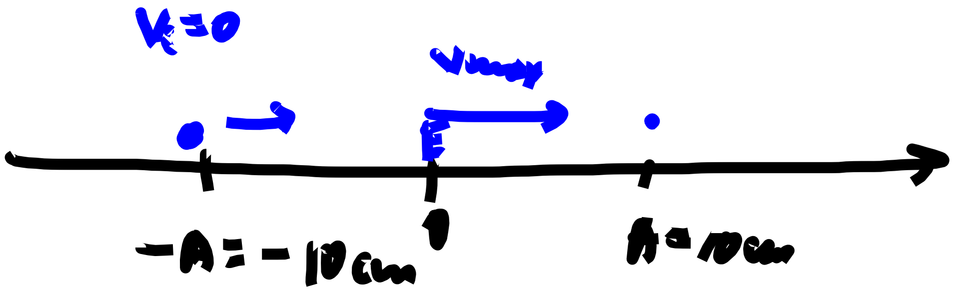
$v = v_m \cos \omega t$

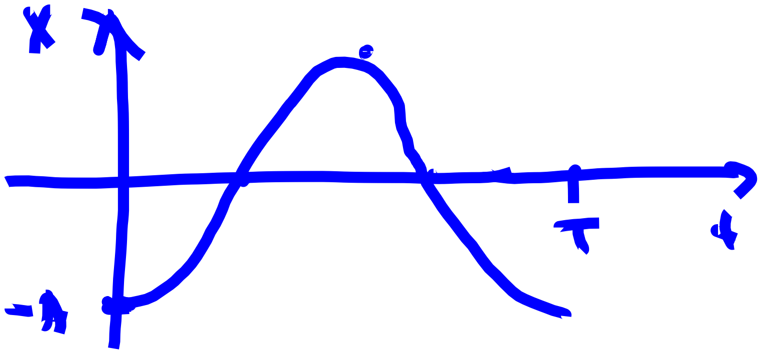
$F_x = m a_x$

An object is released from rest

A 100 g block attached to a spring with *k* = 10 N/m is moved 10 cm to the *left* away from the equilibrium position and released from *rest*. Write a motion equation and a velocity equation for the block.

A 100 g block attached to a spring with *k* = 10 N/m is moved 10 cm to the *left* away from the equilibrium position and released from *rest*. Write a motion equation and a velocity equation for the block.





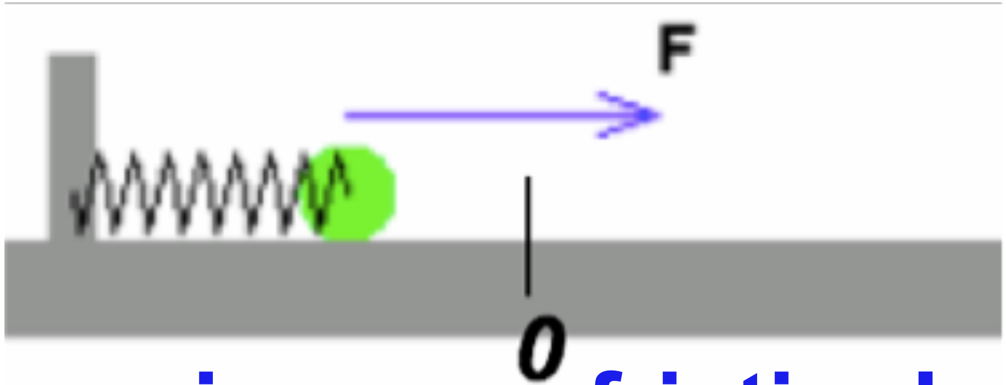
$x = \pm \ \sin \text{ or } \cos \ (\omega \cdot t)$

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

$x = -.1m \cos(10 \cdot t)$

$\omega^2 = \frac{k}{m} = \frac{10}{.1} = 100$

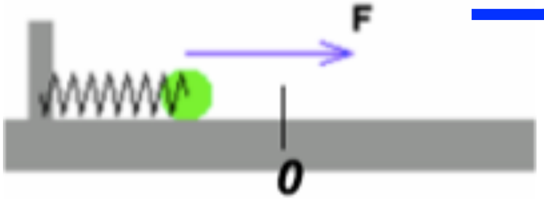
$\omega = \sqrt{100} = 10 \ \frac{rad}{s}$



When an object is making SHM (e.g. a ball attached to an ideal spring and moving on a frictionless surface), its *KE* …

1. Conserved
2. Positive when the ball is to the right to equilibrium, but negative when the ball is to the left to the equilibrium
3. Never negative
4. Never positive
5. None of the above

1. $X_{equilibrium} = 0$ ($E = 0$)
2. Released from rest
3. $X_0 = A > 0$



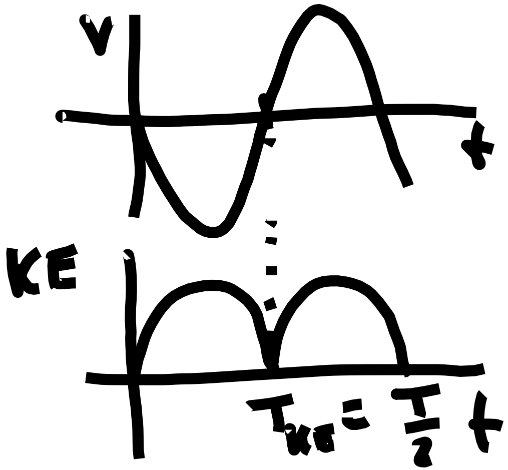
Dynamics of SHM

Energy: What is *happening* to KE?

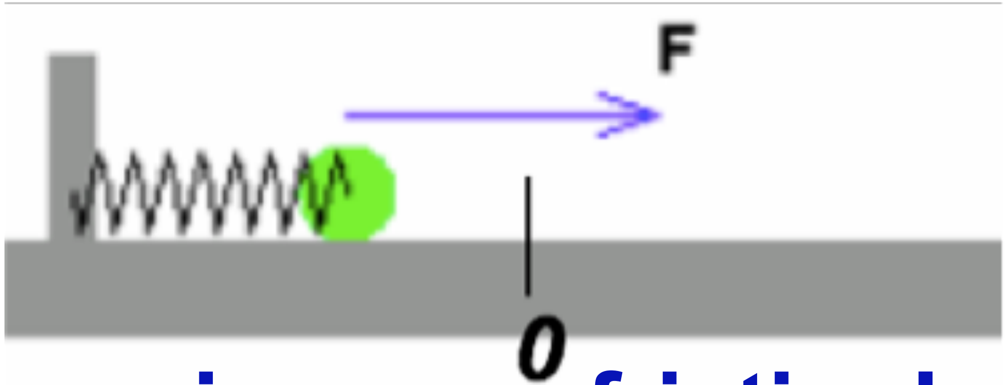
When an object is making SHM (e.g. a ball attached to an ideal spring and moving on a frictionless surface), its *KE* ….

1. Conserved
2. Positive when the ball is to the right to equilibrium, but negative when the ball is to the left to the equilibrium
3. Never negative
4. Never positive
5 None of the above

$KE = \frac{mv^2}{2}$



SHM

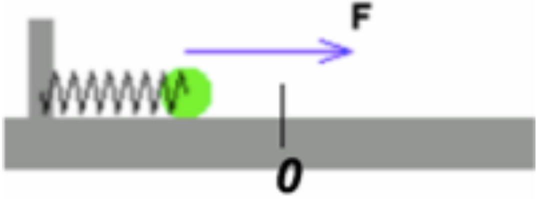


When an object is making SHM (e.g. a ball attached to an ideal spring and moving on a frictionless surface), its *KE* …

~~1. Conserved~~ ~~2. Positive when the ball is to the right to equilibrium, but negative when the ball is to the left to the equilibrium~~

3. Never negative ~~4. Never positive~~

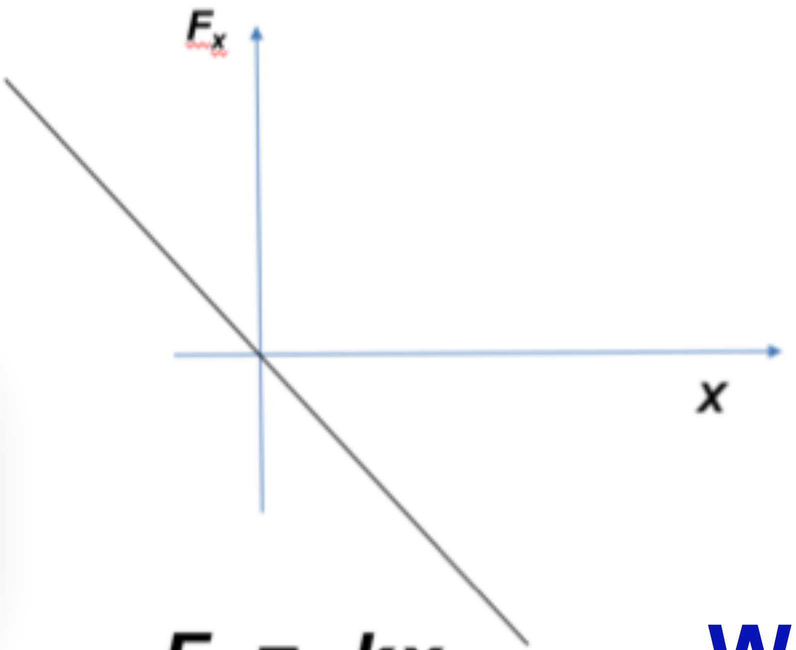
~~5. None of the above~~ AND changes!



Dynamics of SHM

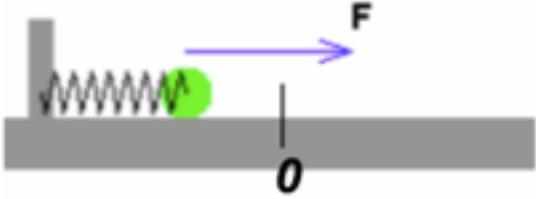
Why does *KE* change?

Because F_{el} does mechanical work!



$$F_x = -kx$$

WKET: $W_{net} = W_{el} = KE_f - KE_i$

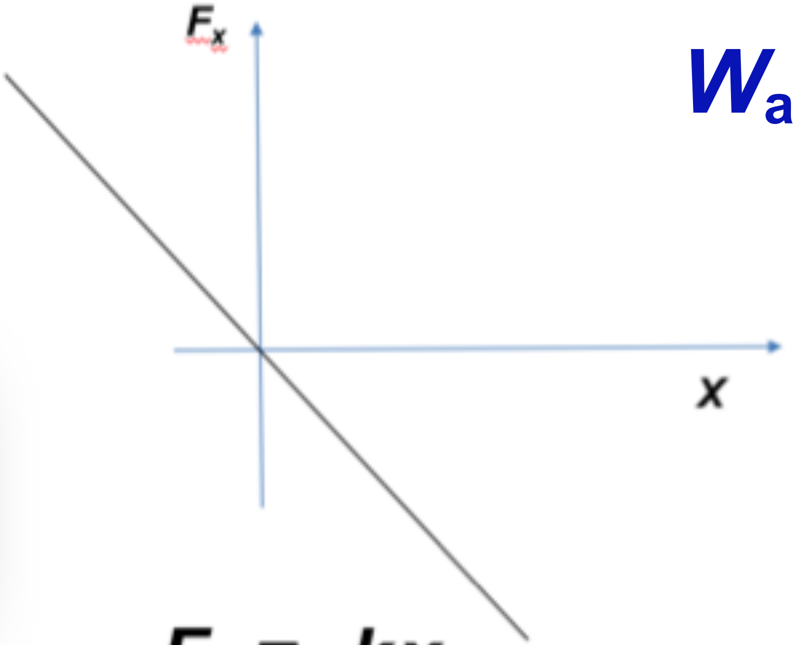


W_{el} = ????

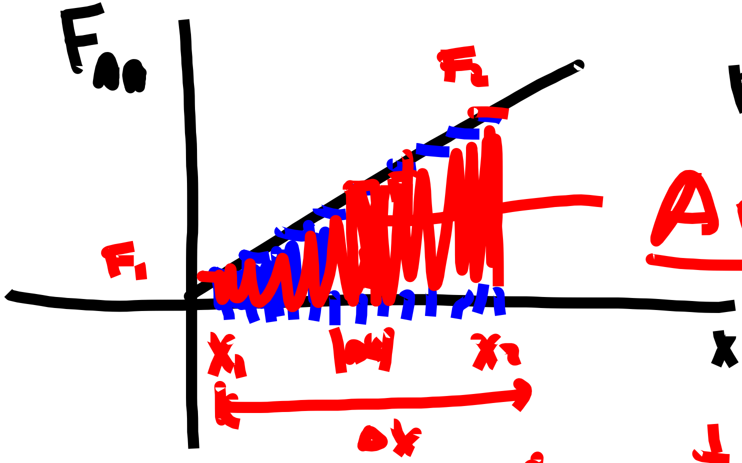
W_{el} = Work done BY a spring

W_{app} = Work done ON a spring

$W_{el} = -W_{app}$



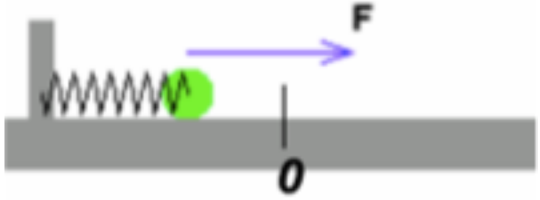
$F_x = -kx$



$W = |F| \cdot |s| \cdot \cos\theta$

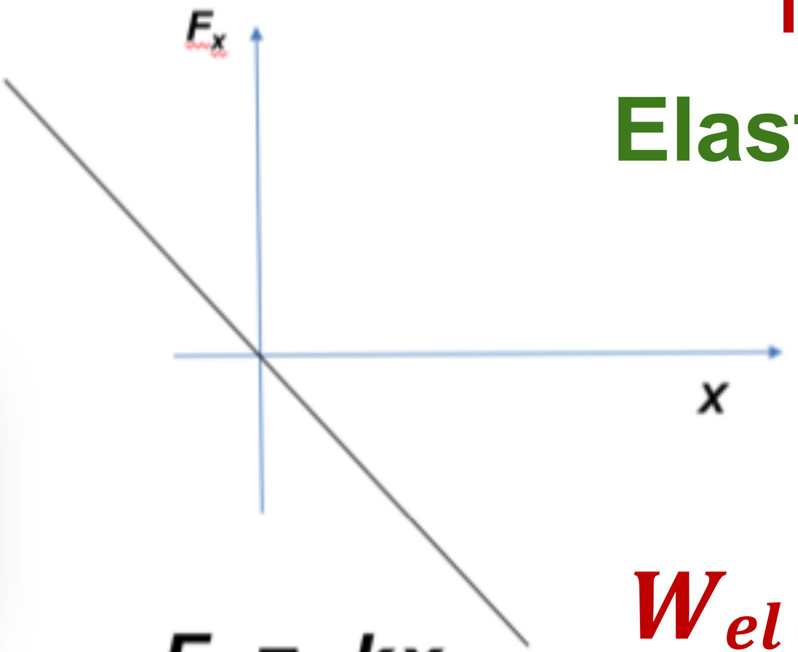
Area

$\text{Area} = \frac{1}{2}(F_1 + F_2) \cdot \Delta x$



Dynamics of SHM

$x_E = 0$



$F_x = -kx$

Work; KE, Elastic Potential Energy (EPE)

If F = const => $W_F = |F||\Delta S|\cos\theta$

Elastic force is *NOT* constant!

Work done *by* the spring!

$$W_{el} = \frac{kx_i^2}{2} - \frac{kx_f^2}{2}$$

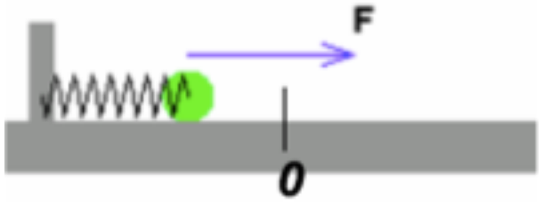
$$PE_{el} = \frac{kx^2}{2}$$

WKET: $W_{net} = W_{el} = KE_f - KE_i$

Graphs for kinetic and potential energy: (t)

of what?

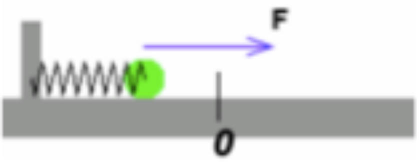
$$KE = \frac{mv^2}{2}$$



$$PE_{el} = \frac{kx^2}{2}$$

$$ME = KE + PE =$$

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



$$KE = \frac{mv^2}{2} \qquad PE_{el} = \frac{kx^2}{2} \qquad ME = KE + PE$$

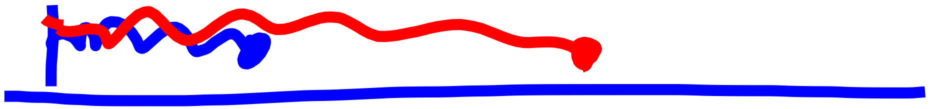
$\Delta x = x - E$

"ball"

Spring

ball

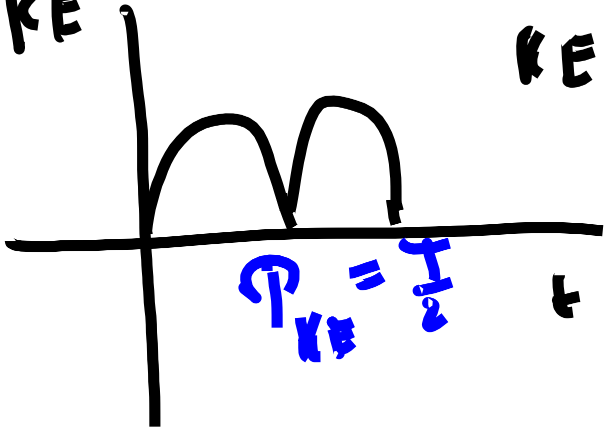
System



$$\frac{mv_i^2}{2} + \frac{kx_i^2}{2} = \frac{mv_f^2}{2} + \frac{kx_f^2}{2}$$

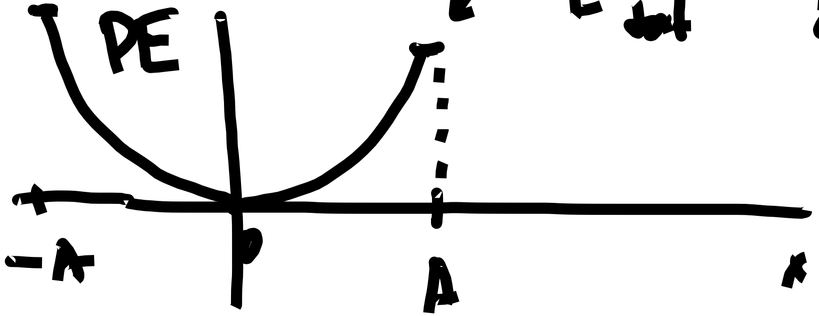
Graphs for kinetic and potential energy: (x)

$KE = \frac{mv^2}{2}$

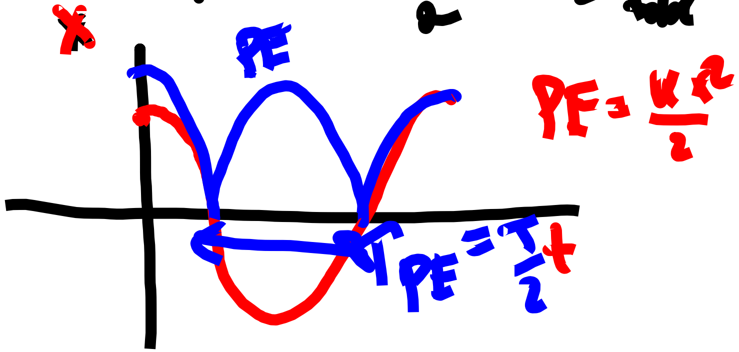


$PE = \frac{k \cdot x^2}{2}$

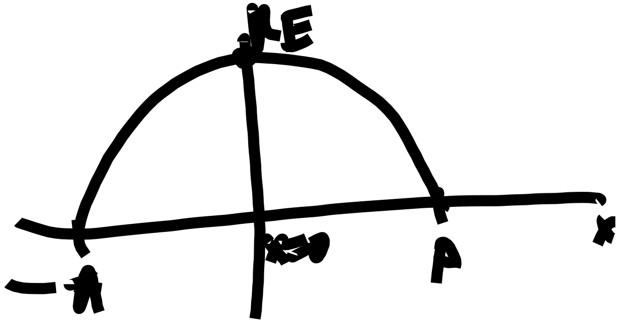
$E_{tot} = \frac{kA^2}{2}$

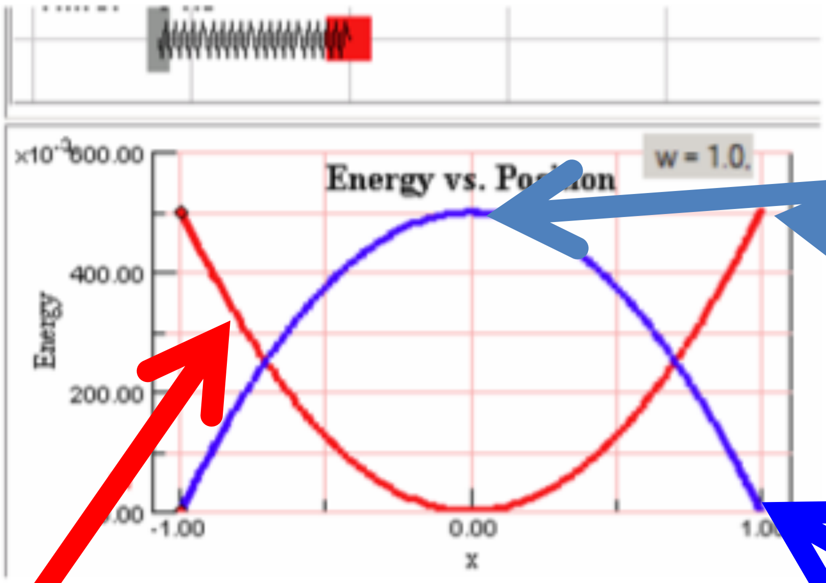


$KE + \frac{k \cdot x^2}{2} = E_{tot}$



$KE = E_{tot} - \frac{kx^2}{2}; = \frac{kA^2}{2} - \frac{kx^2}{2}$





E_{total}

Neglecting friction

=> $ME = const$

LCME

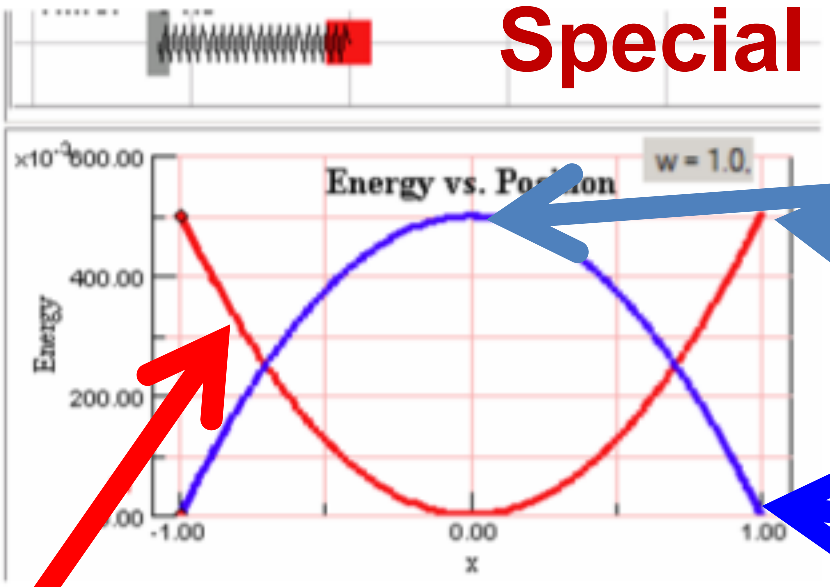
(horizontal spring)

$$U = \frac{kx^2}{2}$$

$$K = \frac{mv^2}{2}$$

$$\frac{mv^2}{2} + \frac{kx^2}{2} = ME = const$$

$$ME_{total} = KE + U = const = KE_1 + U_1 = KE_2 + U_2$$



Special case

$X = A\cos(\omega t)$

$V = A\omega\sin(\omega t)$

Neglecting friction => LCME

E_{total}

$K = E_{total} - U$

$$\boxed{U = \frac{kx^2}{2}} = \frac{k[A\cos(\omega t)]^2}{2} = = U_{\max}\cos^2(\omega t) = E_{total}\cos^2(\omega t)$$

$$\boxed{K = \frac{mv^2}{2}} = \frac{m[A\omega\sin(\omega t)]^2}{2} = = K_{\max}\sin^2(\omega t) = E_{total}\sin^2(\omega t)$$

$$\sin^2(\omega t) + \cos^2(\omega t) = 1 \Rightarrow U + K = \text{const} = E_{total} = U_{max} = K_{max}$$