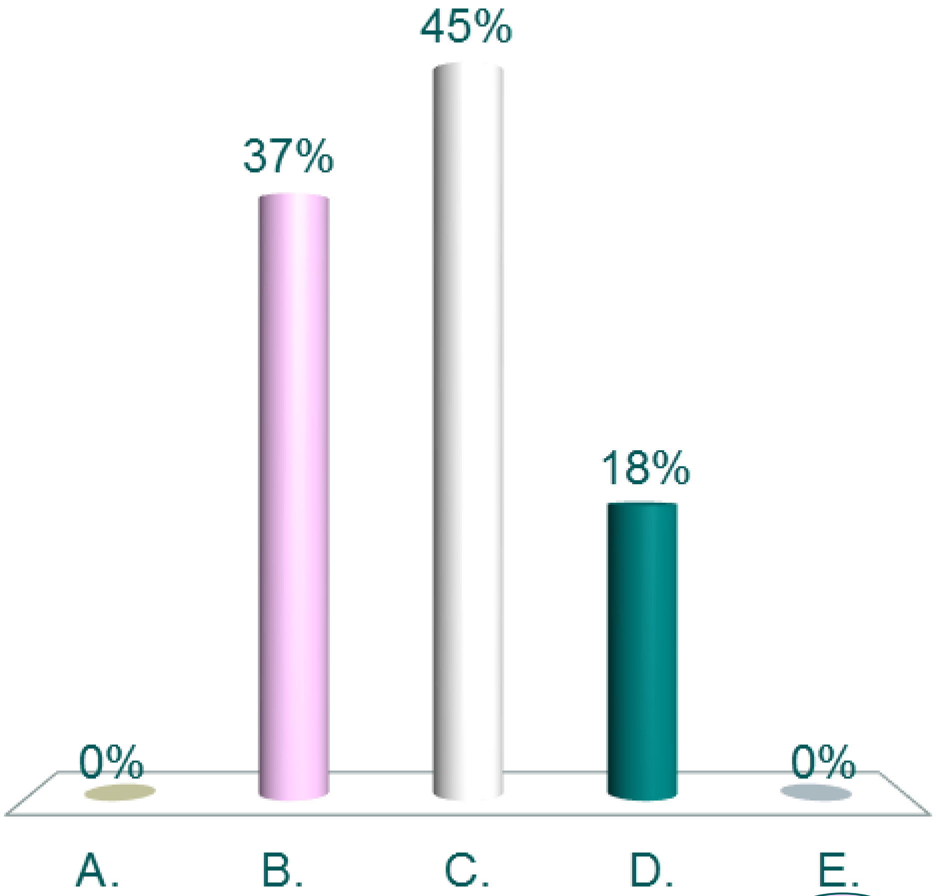
Physics 115 Lecture 2

Describing oscillation

January 25, 2018

What is your year in school?

A. First-Year Student
B. Sophomore
C. Junior
D. Senior
E. I’ve been here, like, *forever*



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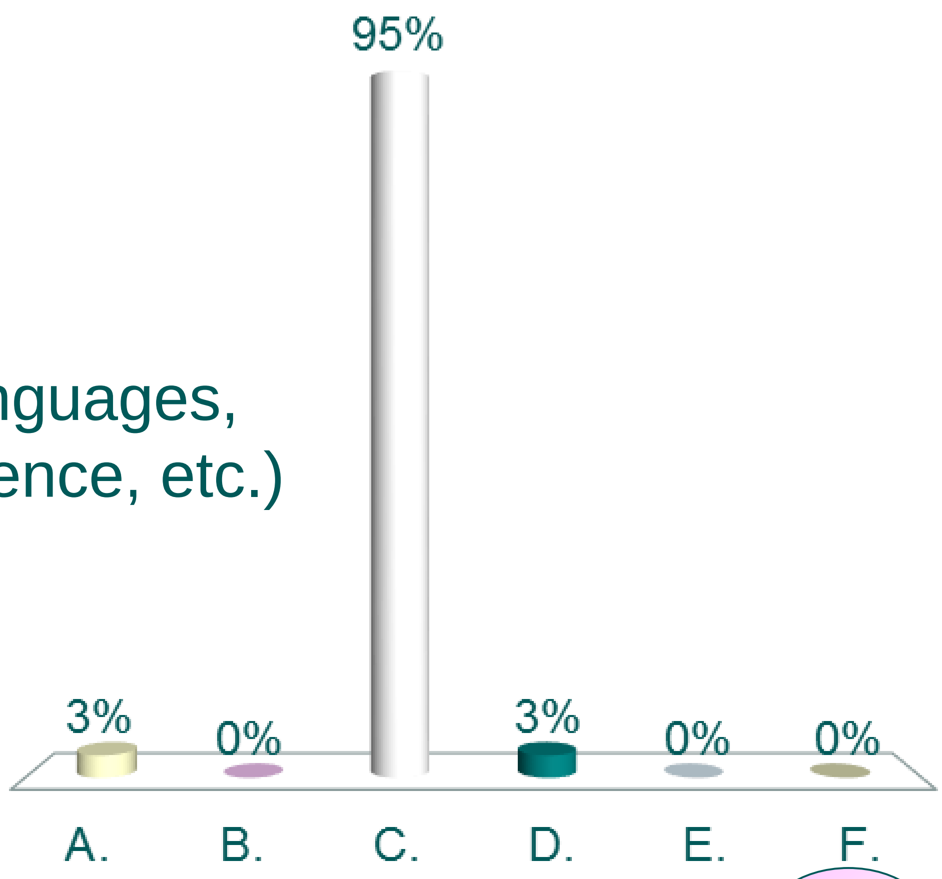
What is your major?

A. Arts or Communication
B. Natural Resources
C. Professional Studies
D. One of the Sciences
E. One of the Humanities (languages, philosophy, political science, etc.)
F. Undeclared



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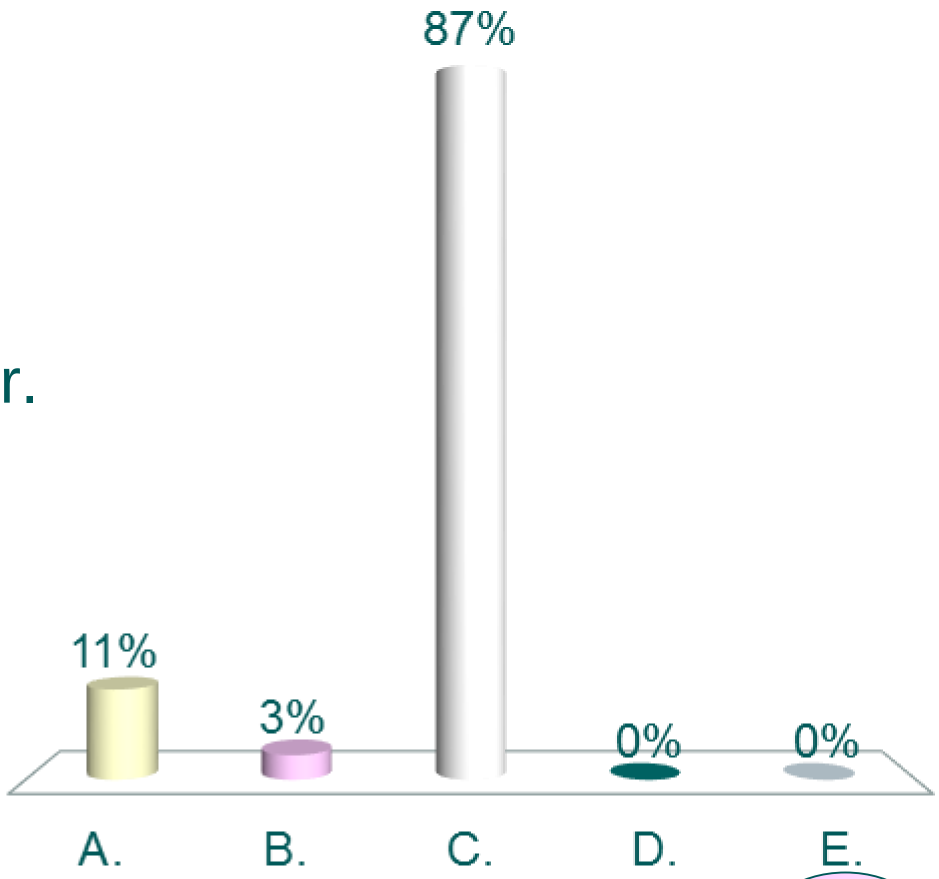
Why are you taking this class?

A. The study of acoustics seems interesting to me.
B. Only because it satisfies GEP requirements.
C. It is required for my major.
D. It was the only class that would fit in my schedule.
E. Some other reason.



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Simple Harmonic Motion

Frequency f = Number of complete cycles per second.
The international unit of frequency is the hertz (Hz)
(1 Hz = 1 cycle per second)

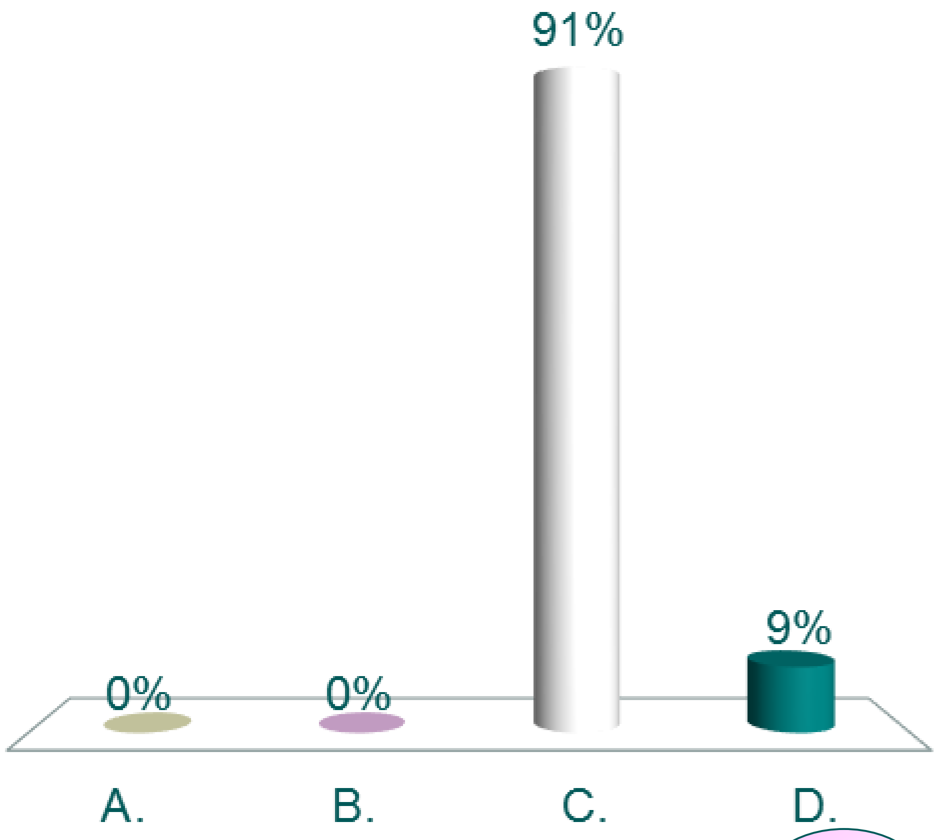
Period T = The time required for one complete cycle.
The metric unit of period is the second (s)

Since "*frequency*" is the number of cycles per second, and "*period*" is the number of seconds per cycle, it follows that *frequency* and *period* are reciprocals of one another.

$$T = \frac{1}{f} \qquad f = \frac{1}{T}$$

You measure your pulse to be 82 beats per minute. What is the period of your heartbeat in seconds?

A. 0.012 s
B. 0.017 s
C. 0.73 s
D. 1.37 s



You measure your pulse to be 82 beats per minute. What is the period of your heartbeat in seconds?

A. 0.012 s

B. 0.017 s

C. 0.73 s

D. 1.37 s

$$T = \frac{1}{f} = \frac{1\ \text{min}}{82\ \text{beats}} \times \frac{60\ \text{s}}{1\ \text{min}} = \boxed{0.73\ \text{s}}$$

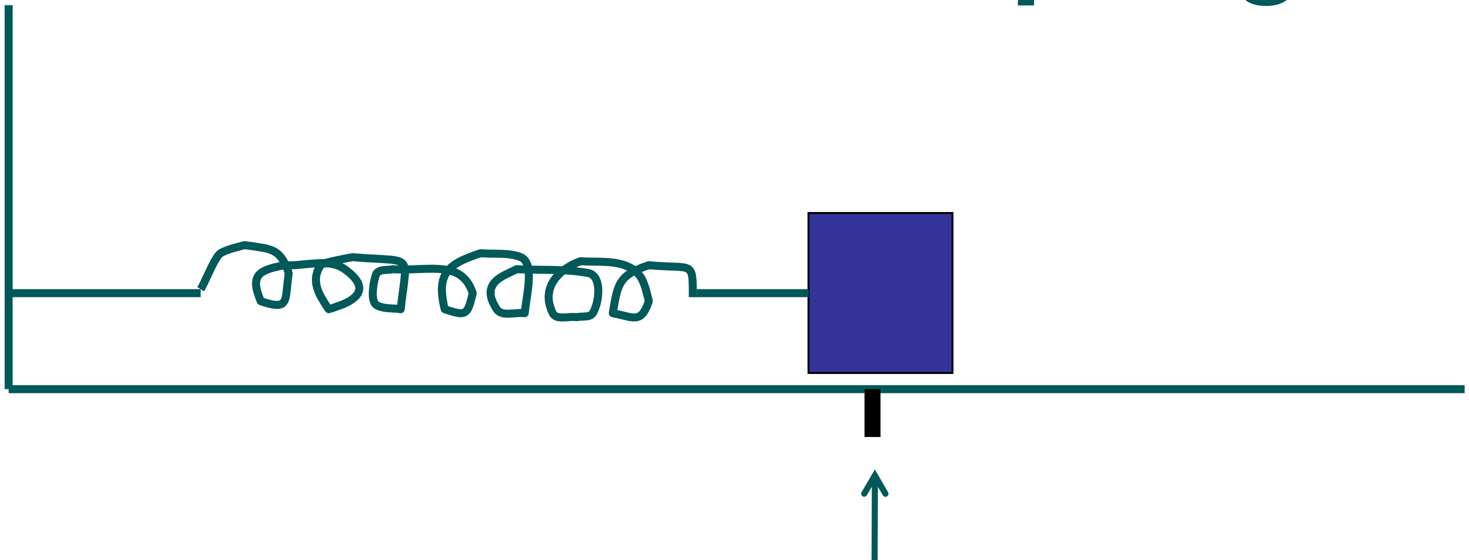
Simple Harmonic Motion

- Two conditions are necessary for SHM to occur:
  - An object must be displaced from its position of *stable equilibrium* and then released,

    AND

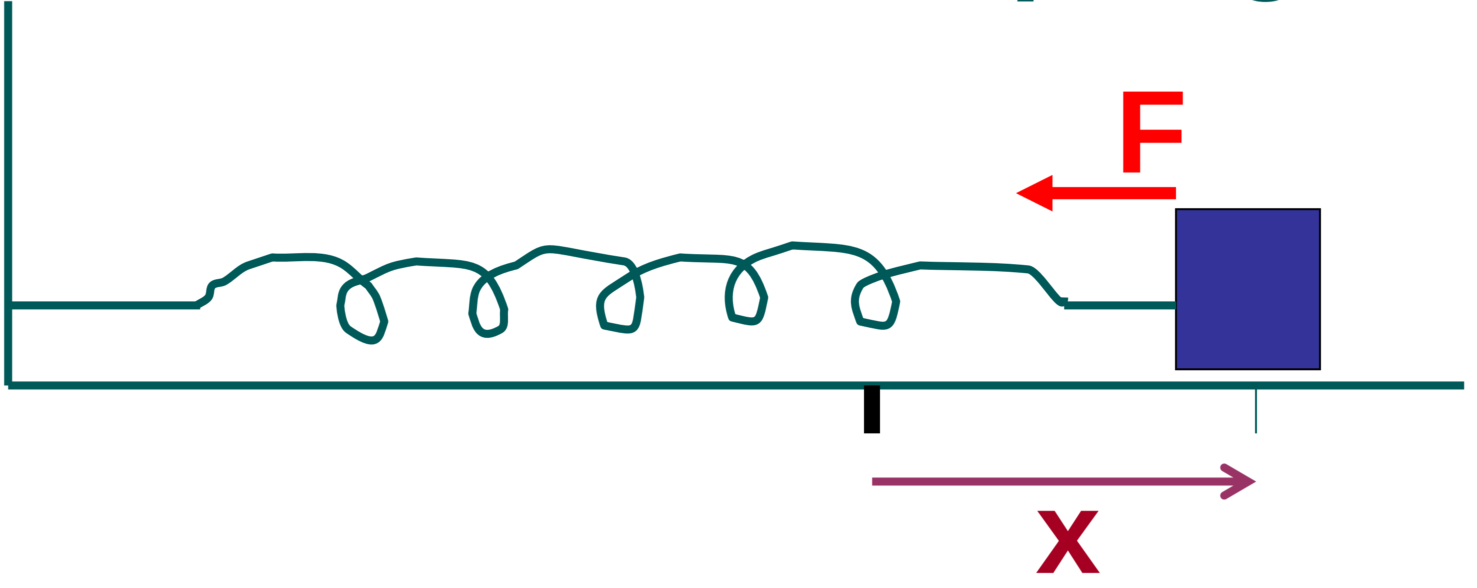
  - the *restoring force* must be directly proportional to the object's displacement from its equilibrium position.

Example: Mass attached to a spring



This is the position of stable equilibrium for the mass shown. When the mass is in this position, the spring is neither stretched nor compressed. With the spring in its relaxed state, there is no restoring force.

Example: Mass attached to a spring



A stretched spring exerts a restoring force that tries to restore the object to its equilibrium position.

Definition of Force

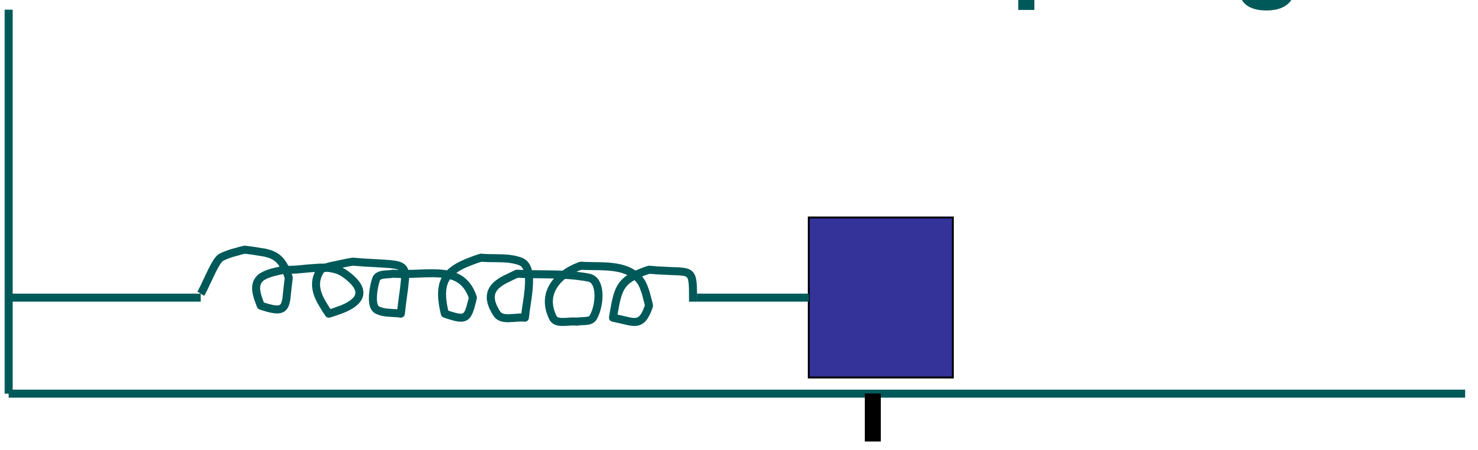
- A force can change the motion of an object.
- A force can be a push or a pull
- Forces accelerate (change the velocity of) masses according to Newton's Second Law

$$\text{force} = \text{mass} \times \text{acceleration}$$

$$F = m \times a$$

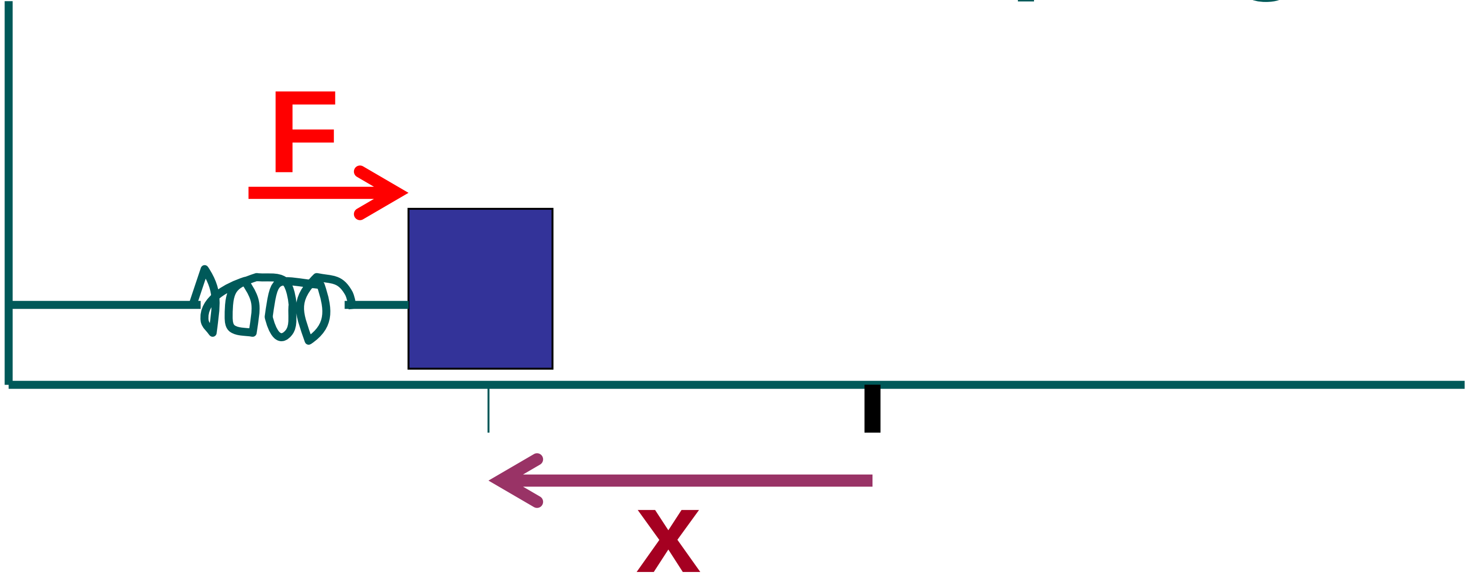
$$\text{N} = \text{kg} \times \frac{\text{m/s}}{\text{s}} = \text{kg}\,\frac{\text{m}}{\text{s}^2}$$

Example: Mass attached to a spring



There is no force on the mass when $x = 0$

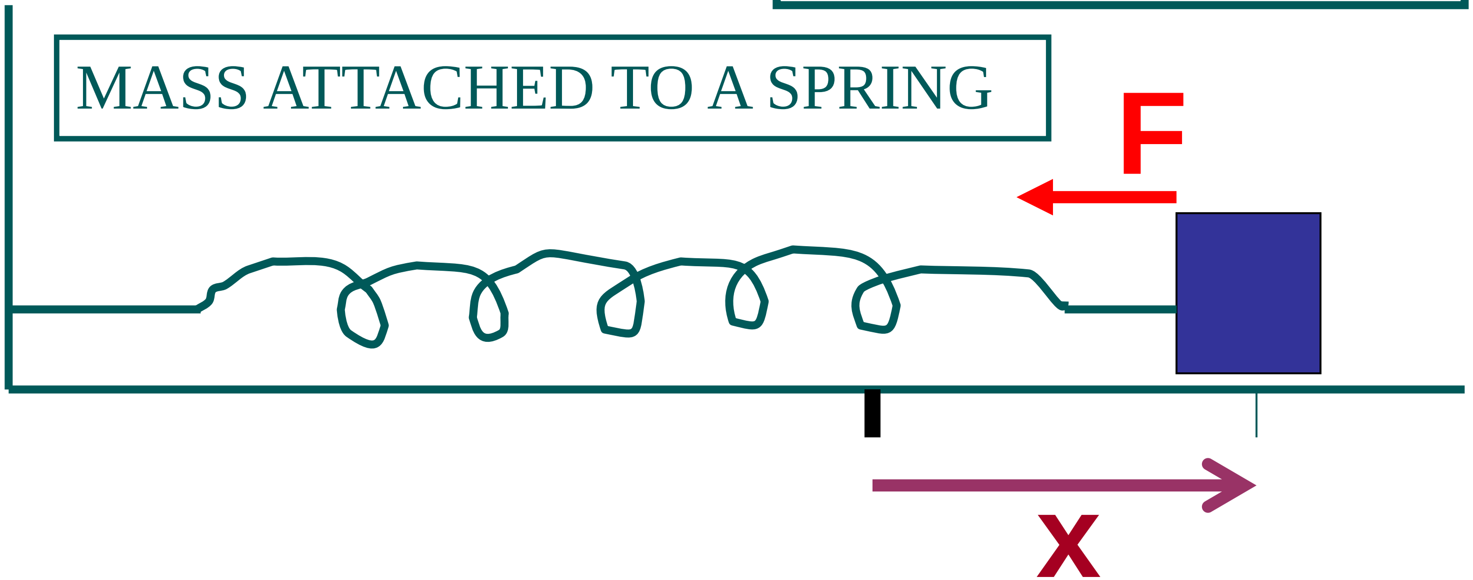
Example: Mass attached to a spring



A compressed spring exerts a restoring force that tries to restore the object to its equilibrium position.

Hooke's law:

$$F = -k\,x$$

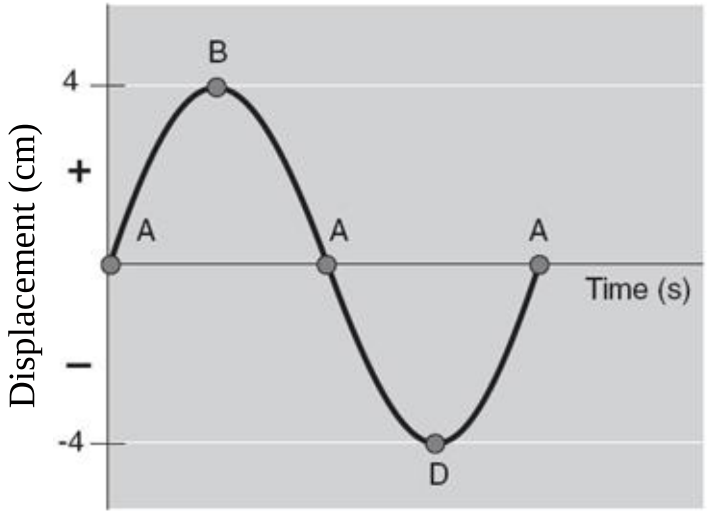


For a spring that obeys Hooke's law, ***the magnitude of the restoring force is directly proportional to x***, where *x* denotes the amount by which the mass is displaced from its equilibrium position. (*x* is also the amount by which the spring is stretched or compressed.) . See animation.

Simple Harmonic Motion

- Hooke's law works for virtually all stable systems, provided that the displacements from the equilibrium configuration are small.
- As long as Hooke's law is obeyed, then SHM will occur if the system is displaced from its equilibrium configuration and then released.

Sinusoidal motion

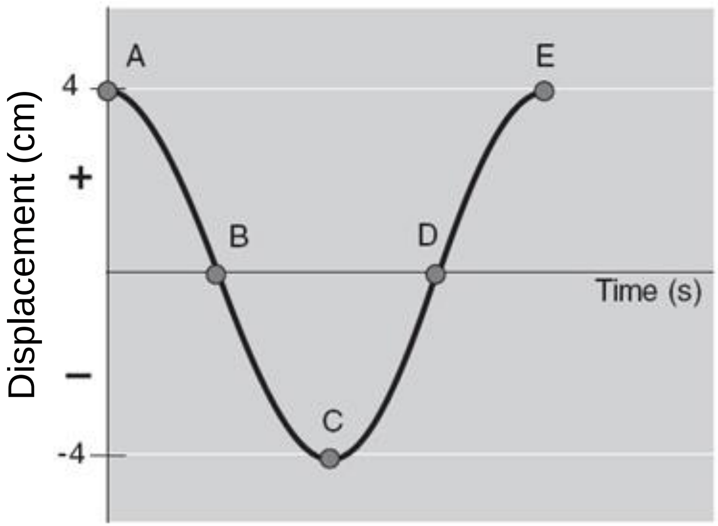


$$x = A\sin(\omega t)$$

$A =$ amplitude (m)

$\omega =$ angular speed (deg/s)

$t =$ time (s)



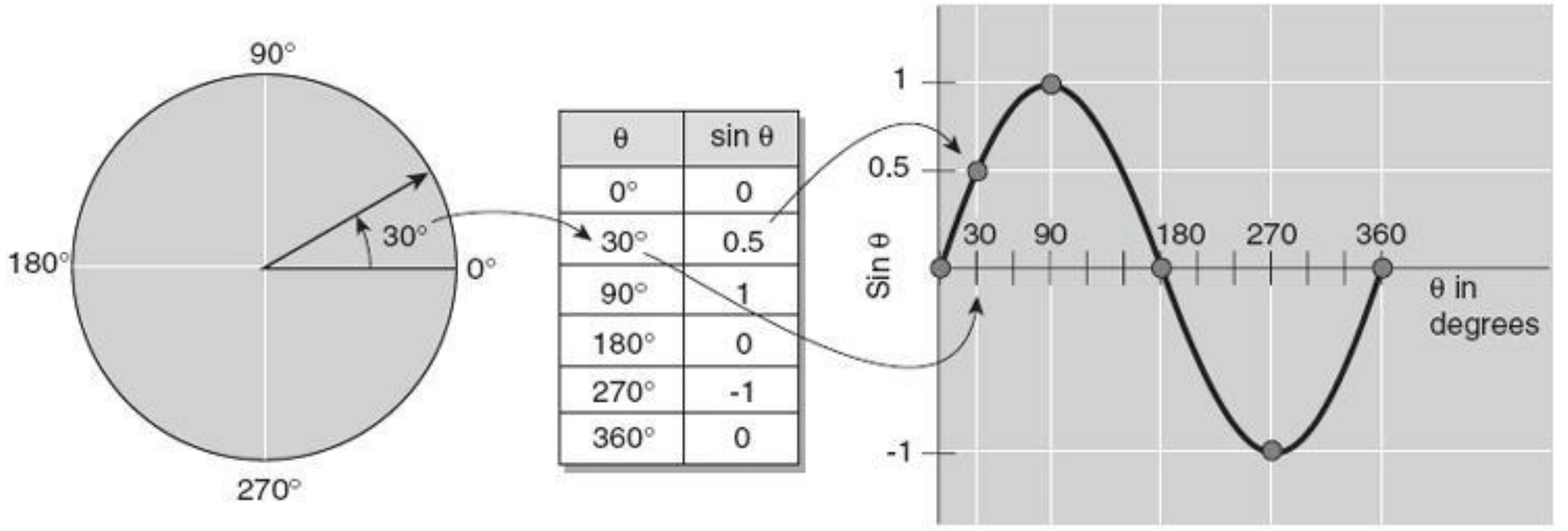
$$x = A\cos(\omega t)$$

Phase

- The stage of the cycle of an oscillator is called its *phase*
- The words *crest*, *trough*, and *zero* can be used to describe the phases corresponding to maximum, minimum, and equilibrium, respectively.
- Because oscillation is described mathematically by a sine or cosine function, the phase is described by an angle θ.
- The natural unit for angle is the radian, where 2π radians = 360°, but we'll stick to degrees.

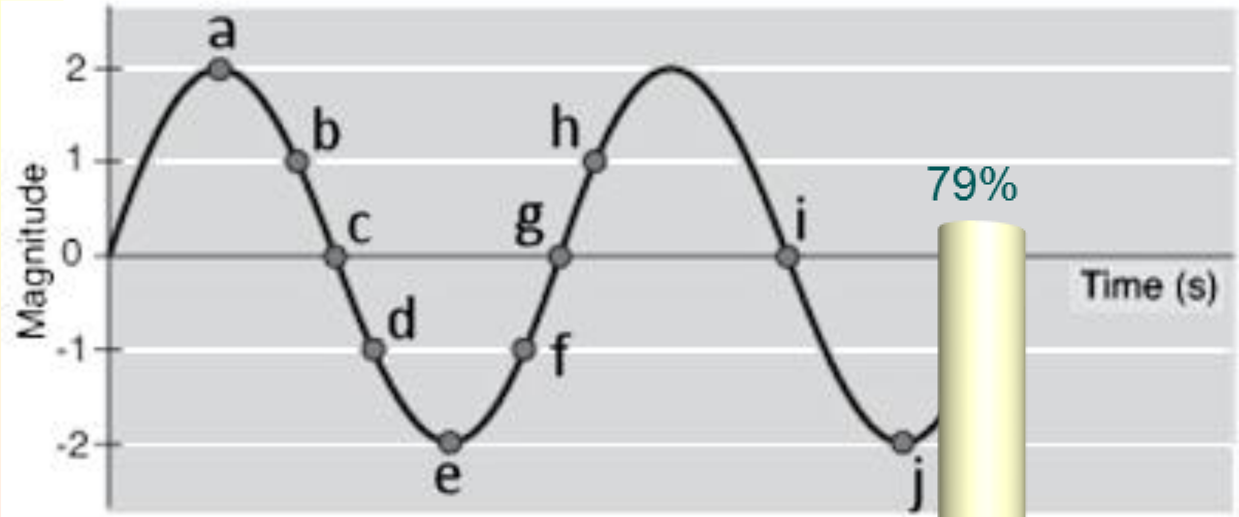
Phase

- Graph sin(*θ)* on the *y* axis vs. the phase angle *θ* on the *x* axis.
- The crest is at 90° and the trough at 270°



θ	sin θ
0°	0
30°	0.5
90°	1
180°	0
270°	-1
360°	0

What is the phase angle at point f in degrees?

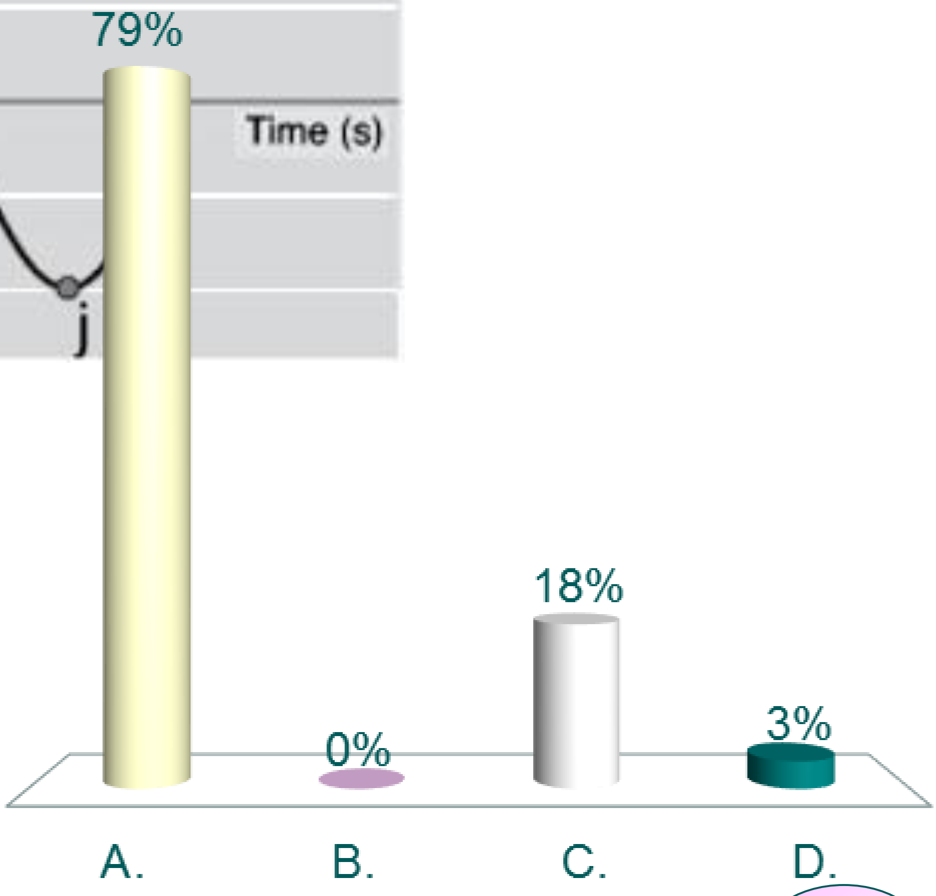


A. 315°

B. 45°

C. 225°

D. 135°



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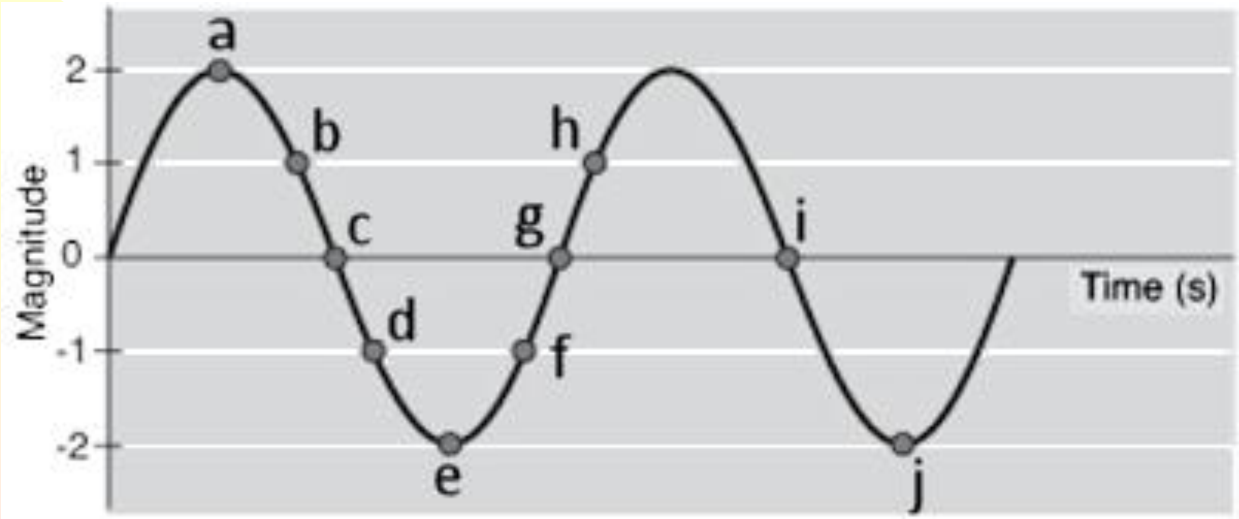
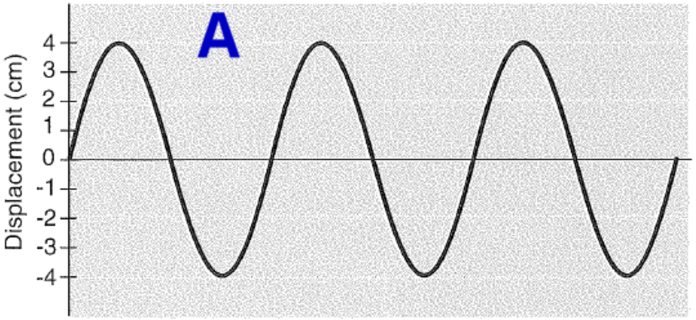
What is the phase angle at point f in degrees?



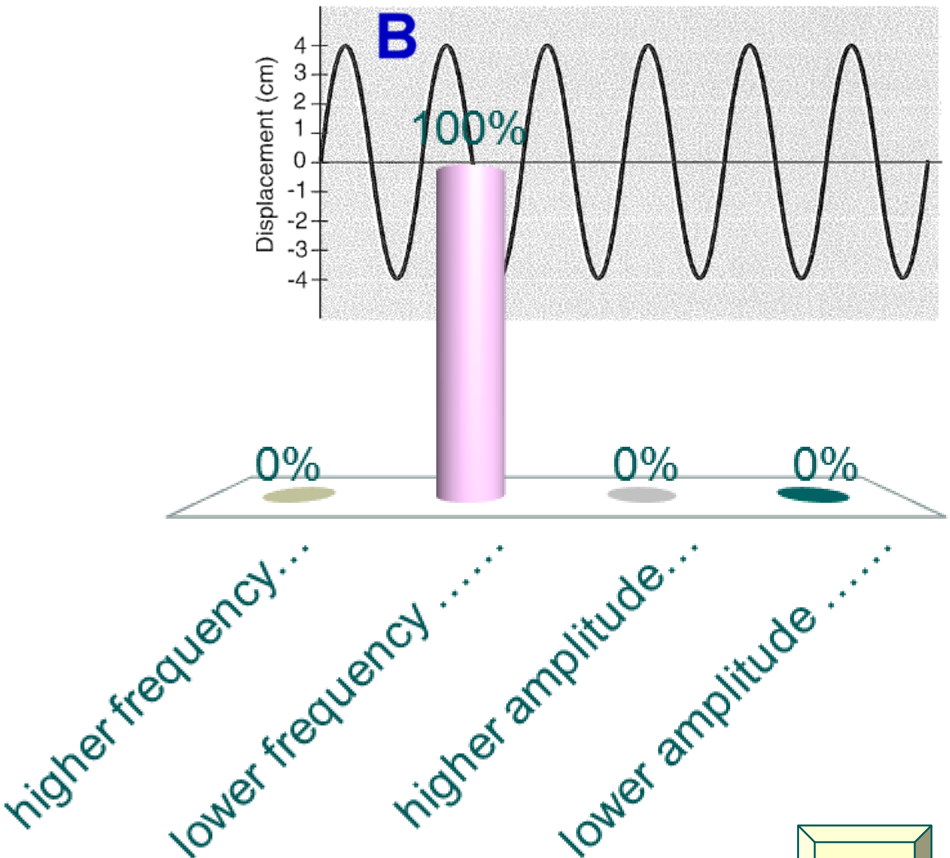
A. 315°
B. 45°
C. 225°
D. 135°

Point c is 180°, point e is 270°, and point g is 360°. Point f must therefore be 270° + 45° = 315°.

Oscillator A has a ____ than oscillator B, but they each have the same ____.



A. higher frequency … amplitude
B. lower frequency … amplitude
C. higher amplitude … frequency
D. lower amplitude … frequency



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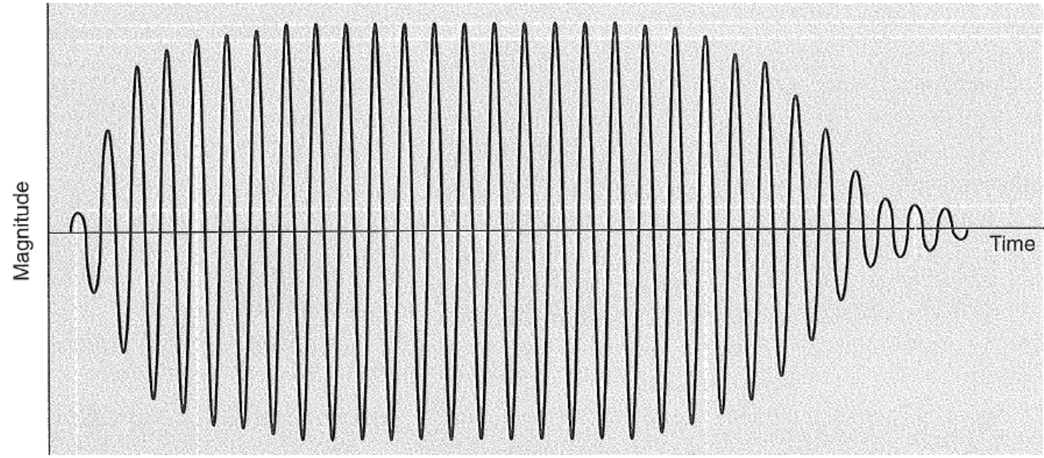
The _____ of this oscillator is changing in time.

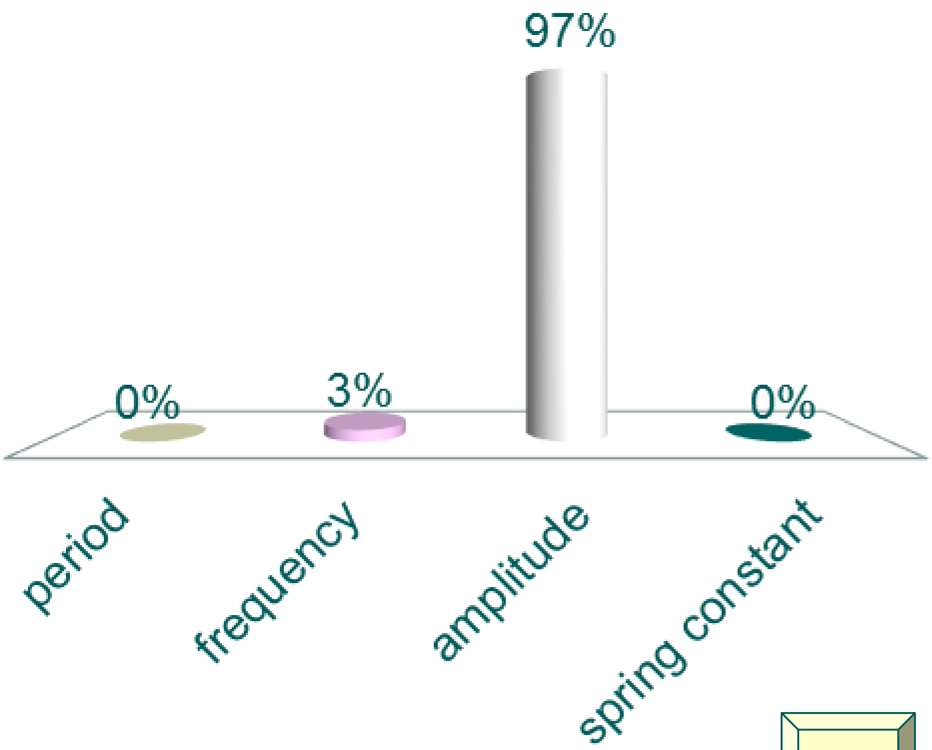


A. period

B. frequency

C. amplitude

D. spring constant



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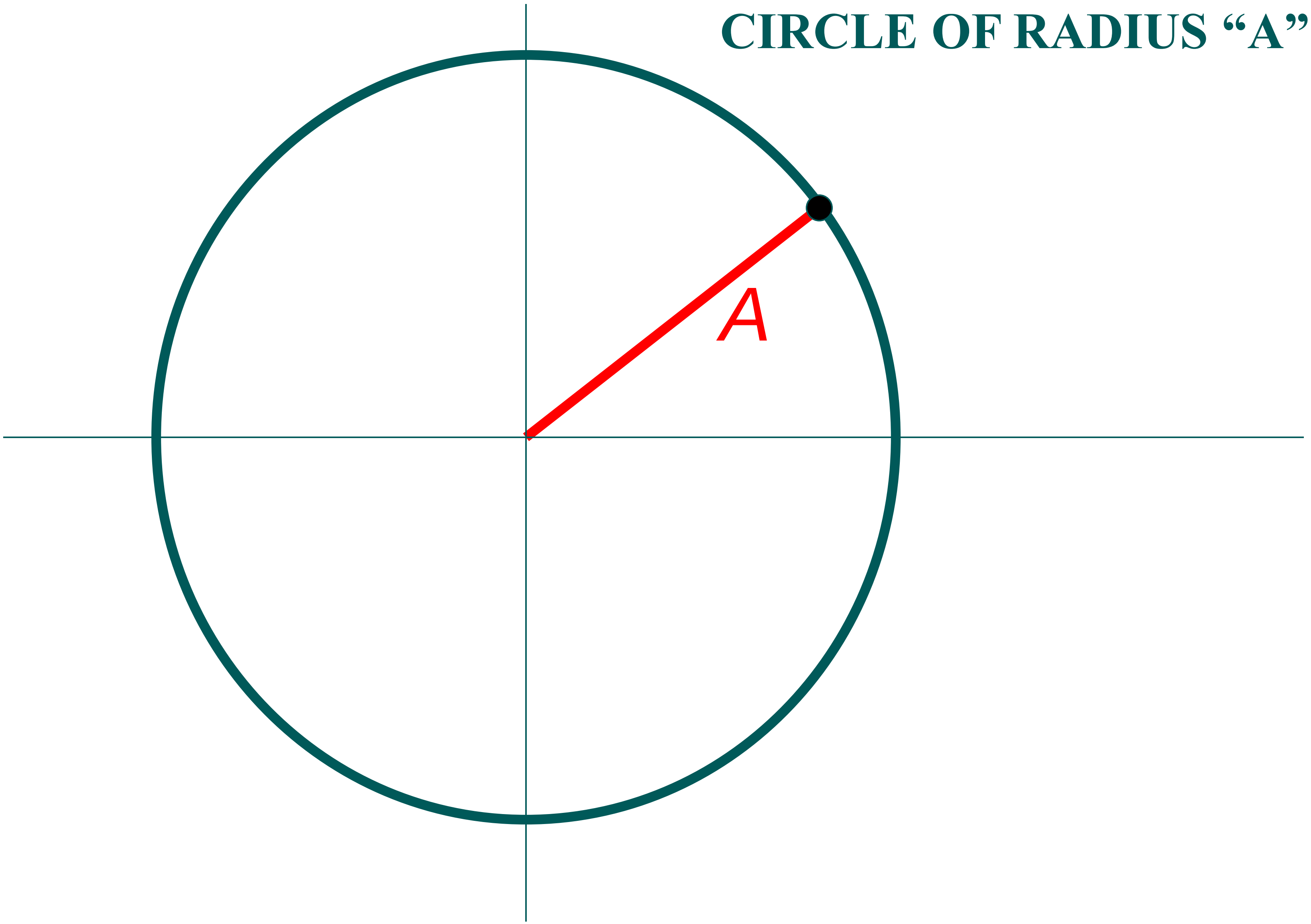
Simple Harmonic Motion

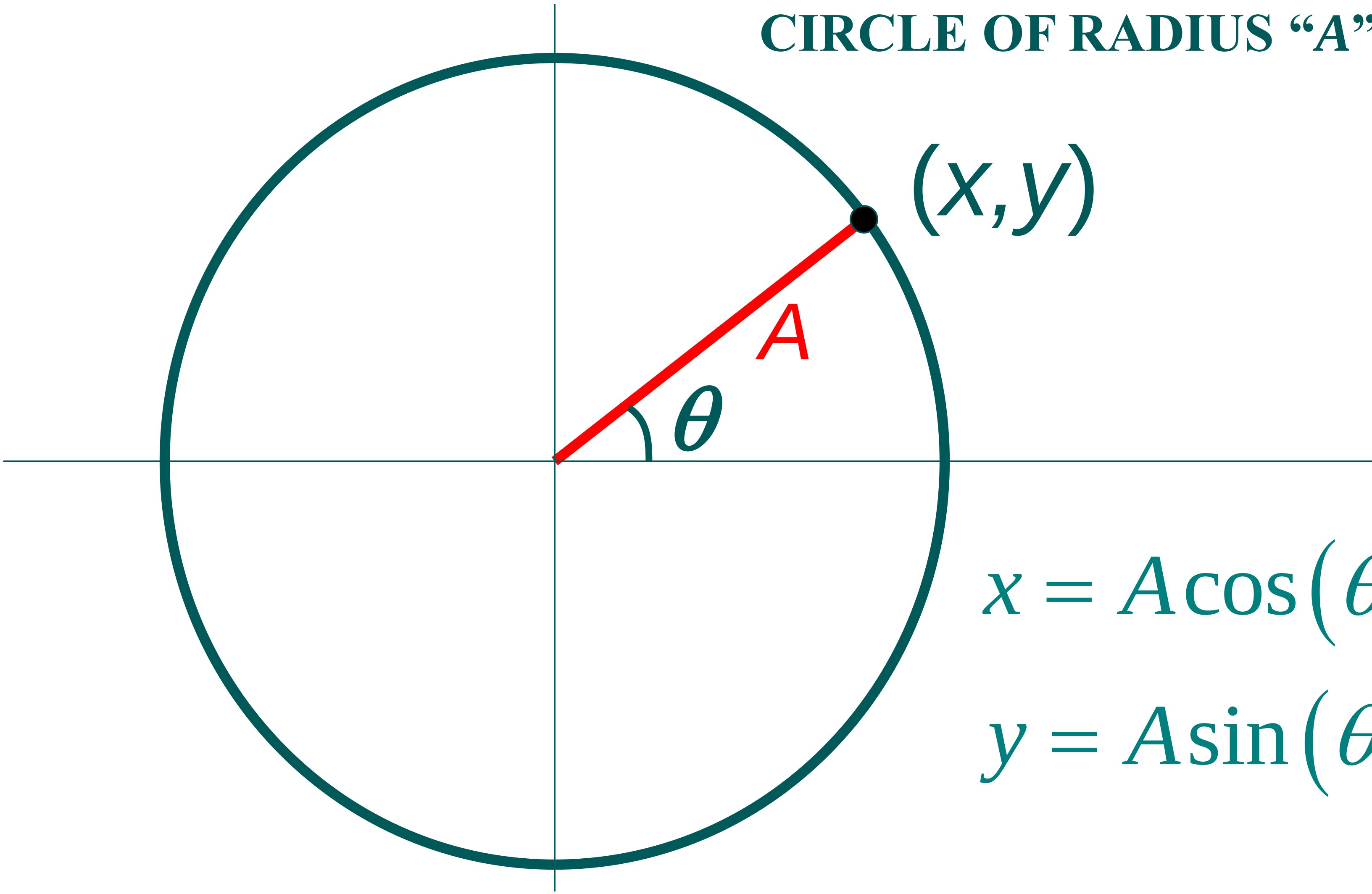
SHM is the projection of uniform circular motion onto a diameter of the circle. See the animation

We will use this idea to write a mathematical description of oscillatory motion.

CIRCLE OF RADIUS "A"



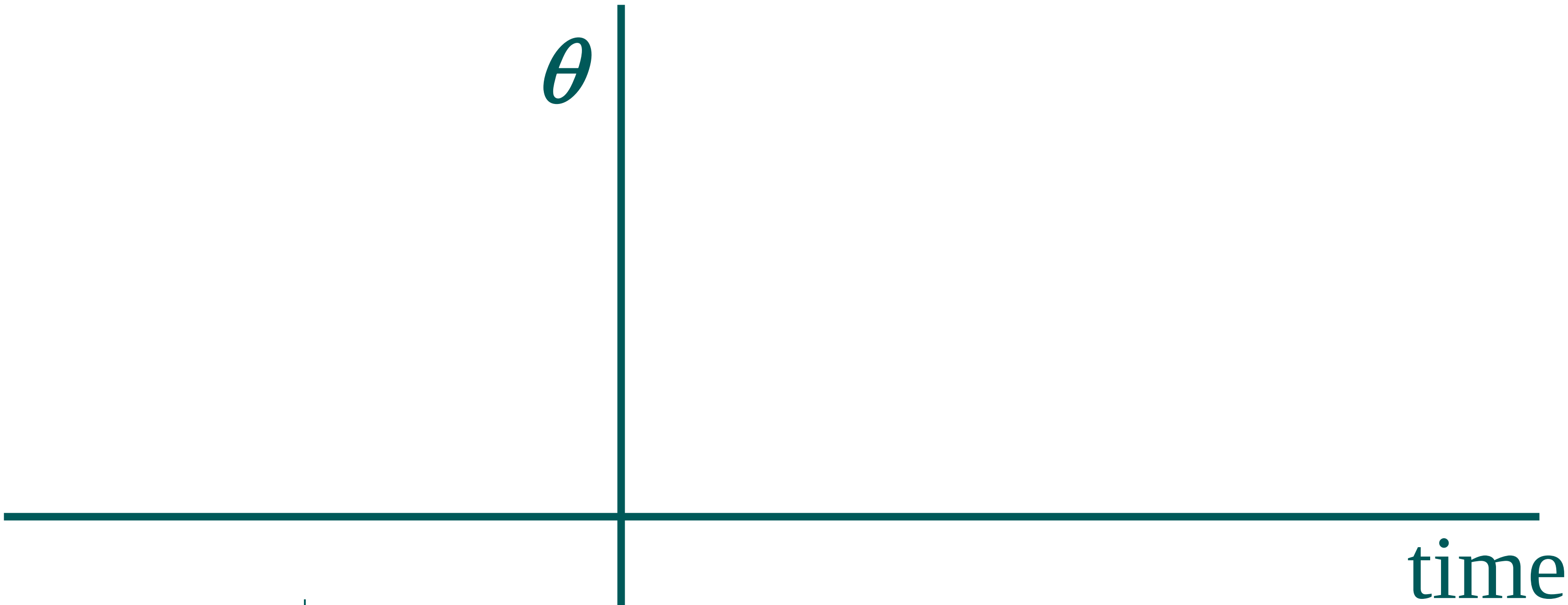
CIRCLE OF RADIUS "*A*"

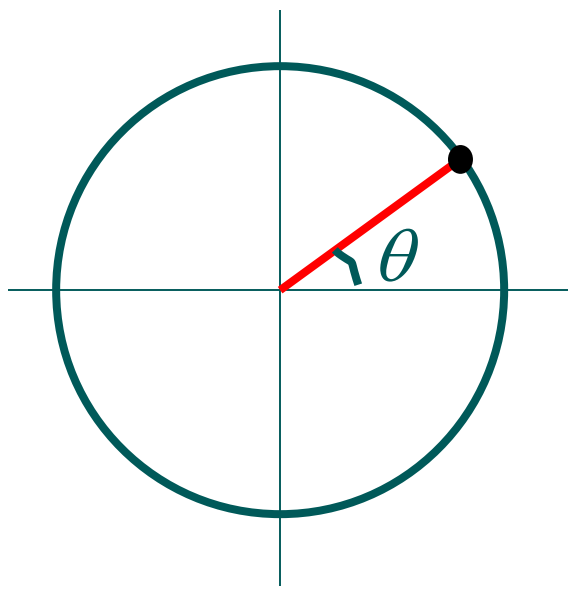


$$x = A\cos(\theta)$$

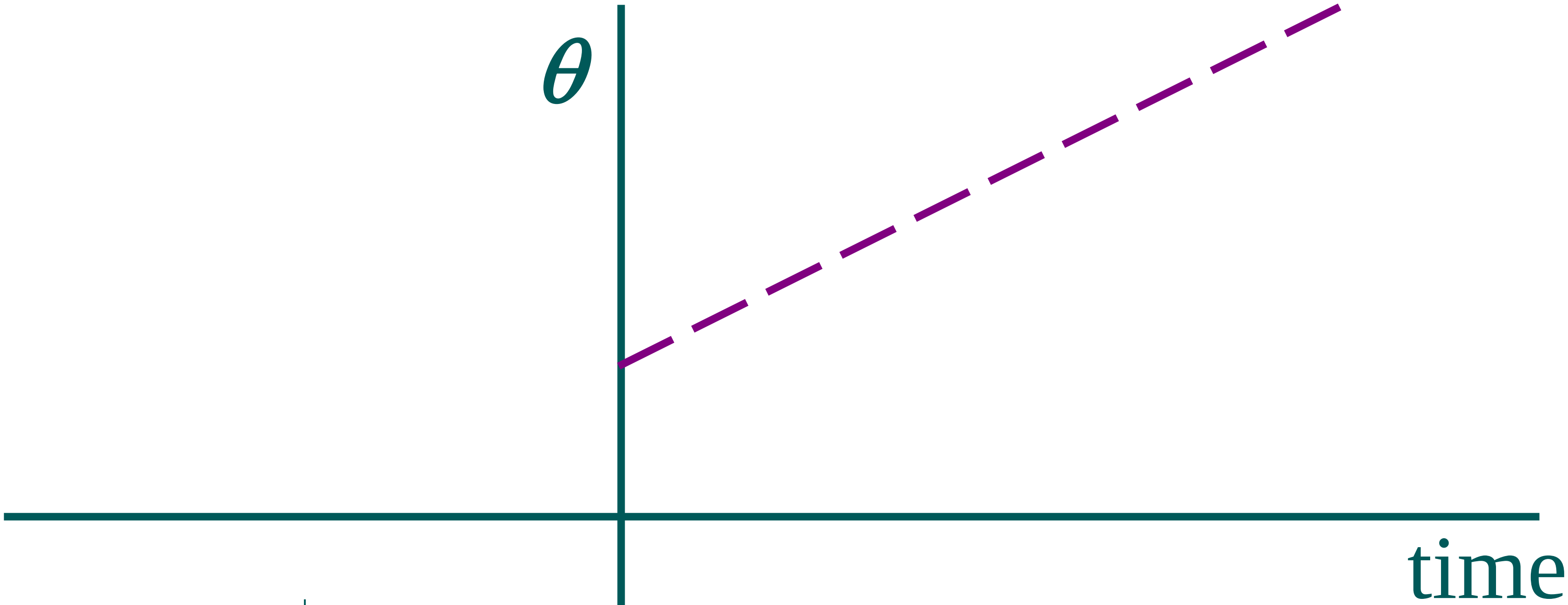
$$y = A\sin(\theta)$$

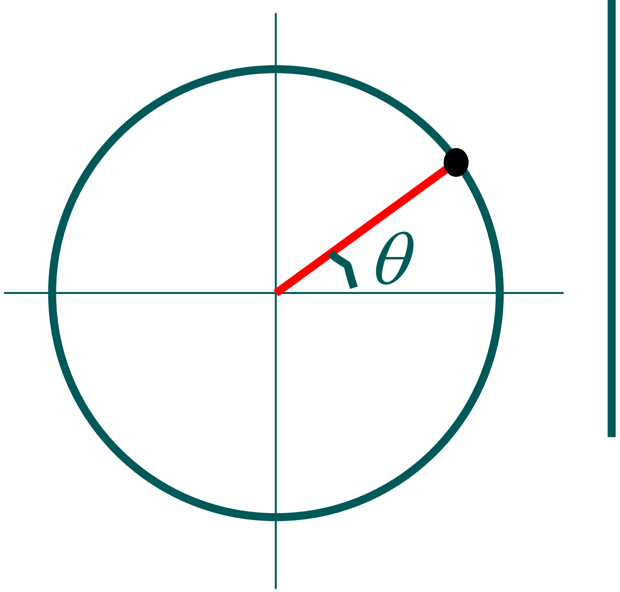
If θ changes with time, then both *x* and *y* also change with time.



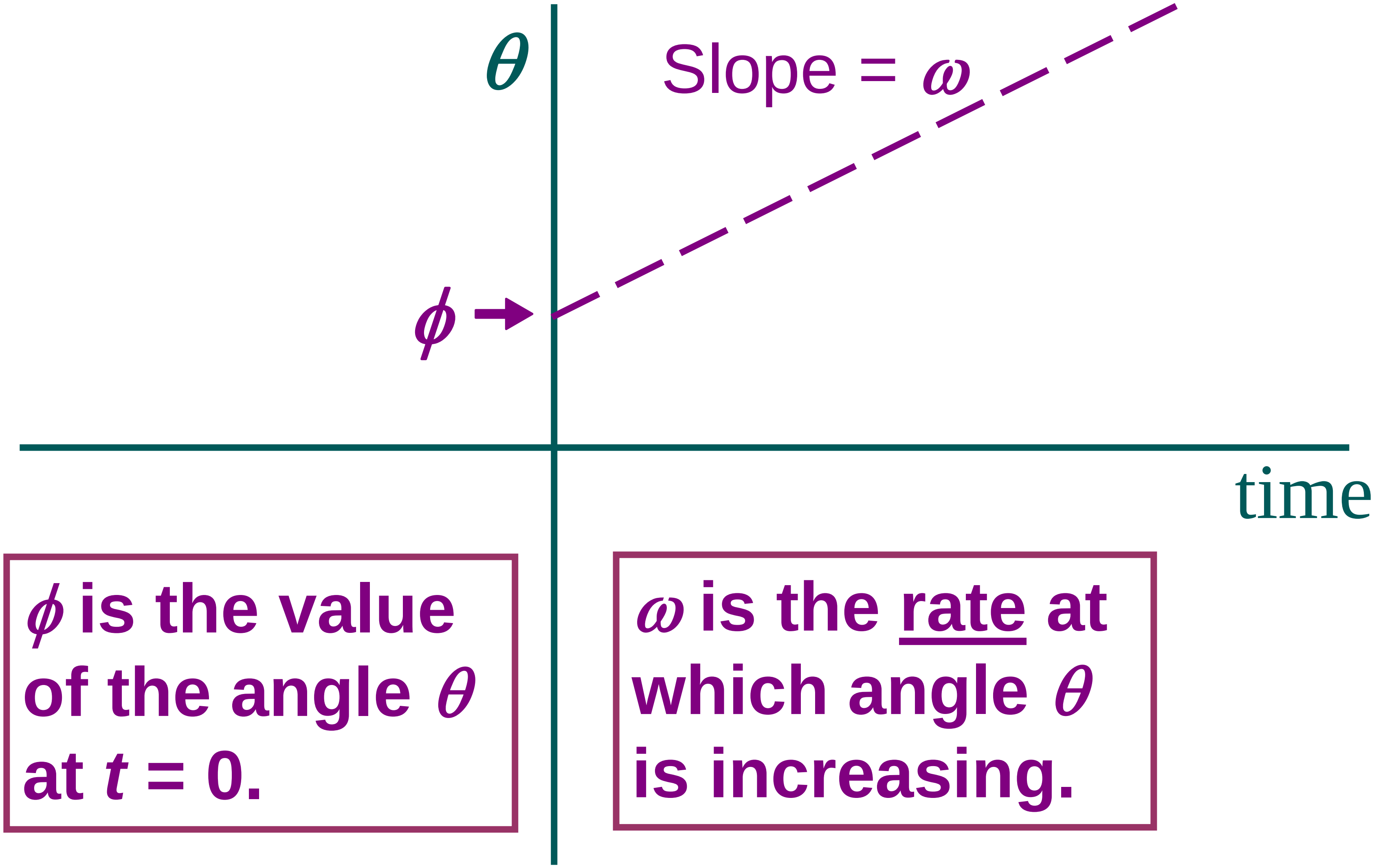


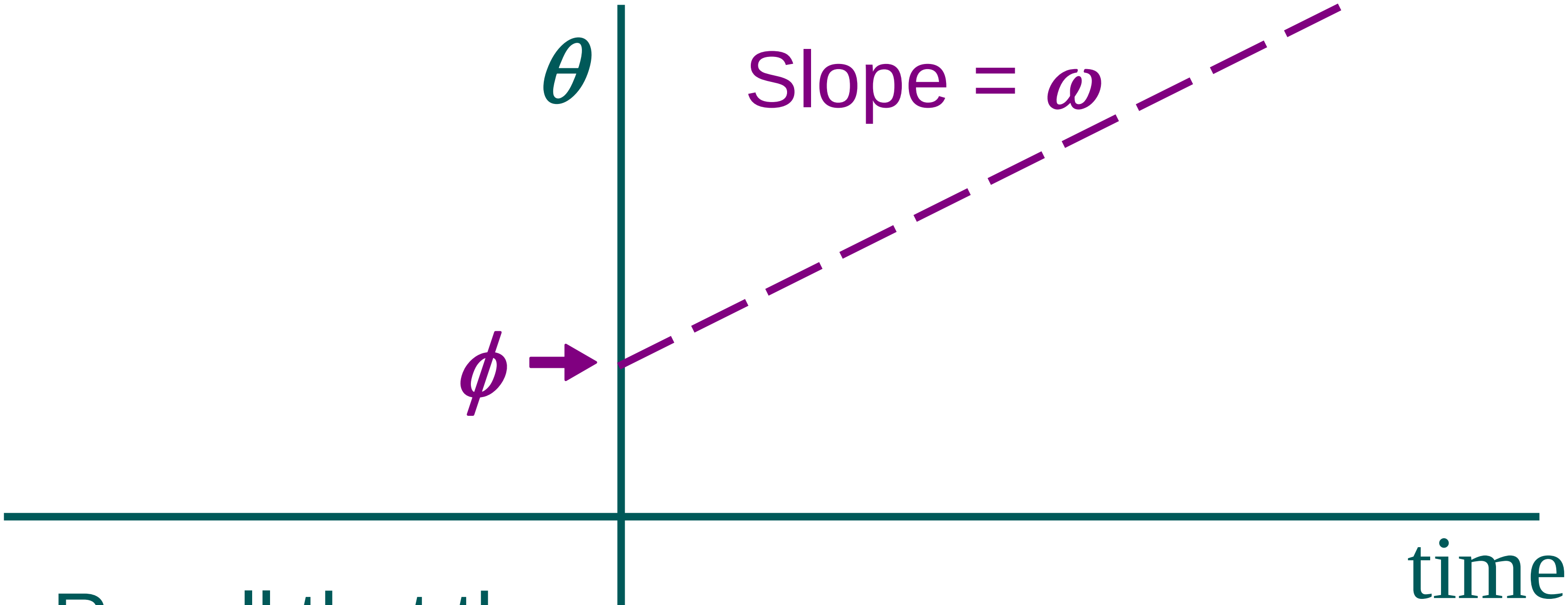
If the black dot moves at a uniform rate along the circumference of the circle, imagine how the angle θ grows with time.





If the black dot moves at a uniform rate along the circumference of the circle, imagine how the angle θ grows with time.


θ
Slope = ω
ϕ
time
ϕ is the value of the angle θ at t = 0.
ω is the rate at which angle θ is increasing.



Recall that the equation for a straight line is:

$y = mx + b$

($y \to \theta$, $m \to \omega$, $x \to t$, $b \to \phi$)

$$\theta = \omega t + \phi$$

Position of a Simple Harmonic Oscillator as a function of time

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

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

$y = A\sin(\theta)$ Plug in $\theta = \omega t + \phi$

$$\boldsymbol{y(t) = A\sin(\omega t + \phi)}$$

Simple Harmonic Motion

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

initial phase angle

time

angular speed

amplitude

displacement as a function of time

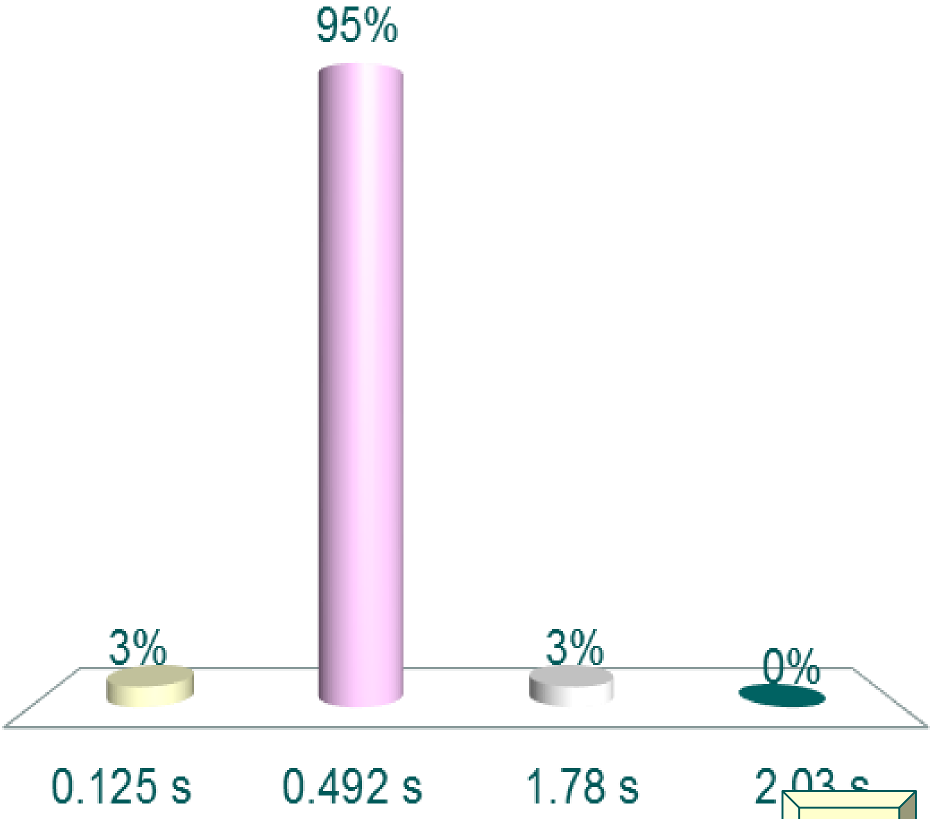
Simple Harmonic Motion

$$y(t) = A\sin(\omega t + \phi)$$

- ϕ: initial phase angle
- t: time
- ω: angular speed
- A: amplitude
- $y(t)$: displacement as a function of time

If ω = 640°/s and φ = 45°, at what time will the phase of the oscillator be 360°?

A. 0.125 s
B. 0.492 s
C. 1.78 s
D. 2.03 s



0

If ω = 640°/s and φ = 45°, at what time will the phase of the oscillator be 360°?

A. 0.125 s

B. 0.492 s

C. 1.78 s

D. 2.03 s

$$\theta = \omega t + \phi$$

$$t = \frac{\theta - \phi}{\omega} = \frac{360° - 45°}{640°/\text{s}}$$

$$t = \boxed{0.492\ \text{s}}$$