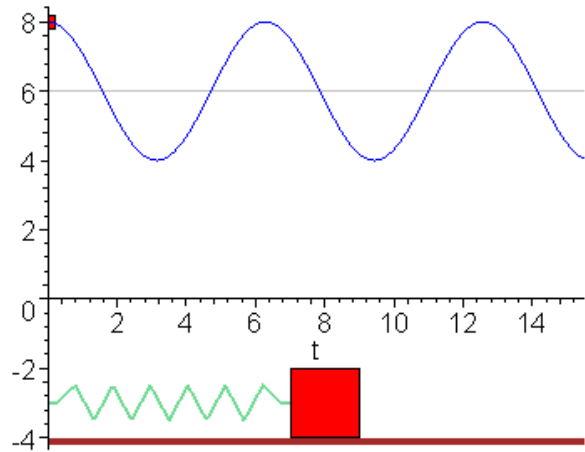


# PHY131H1F - Class 29



**Today:**

10.1 Period and Frequency

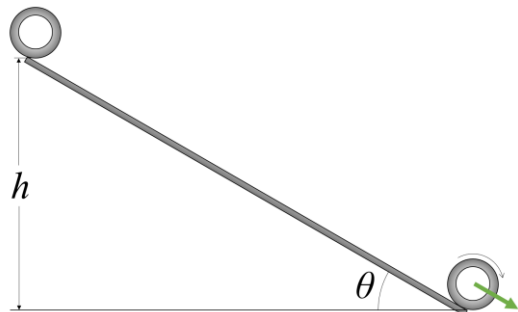
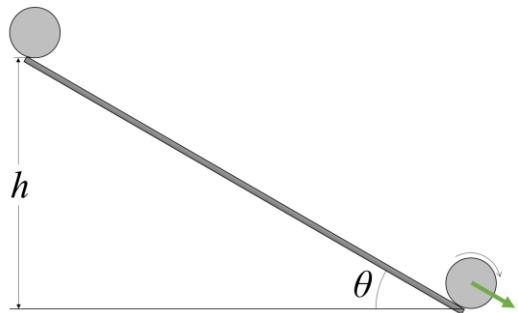
10.2 Simple Harmonic Motion

Animation from [http://www.uni-saarland.de/fak7/knorr/homepages/patrick/theorex/MapleScripts/oscillations/forced\\_oscillations1.html](http://www.uni-saarland.de/fak7/knorr/homepages/patrick/theorex/MapleScripts/oscillations/forced_oscillations1.html)

1

## Ch.9 Poll Question

- A solid disk is released from rest and rolls without slipping down an incline.
  - A hoop with the same mass and radius does the same.
  - Which reaches the bottom with a greater speed?
- A. The disk  
B. The hoop  
C. Both reach the bottom with the same speed



2

A solid disk (hoop) starts from rest and rolls without slipping down an incline. The change in height is  $h$ . What is its speed at the bottom?

SKETCH & TRANSLATE.

REPRESENT MATHEMATICALLY

SIMPLIFY & DIAGRAM

SOLVE & EVALUATE

3

## ...on to Chapter 10

- We have studied linear motion—objects moving in straight lines at either constant velocity or constant acceleration.
- We have also studied objects rotating or moving at constant speed in a circle.
- In this chapter we encounter a new type of motion, in which objects vibrate back and forth.

4

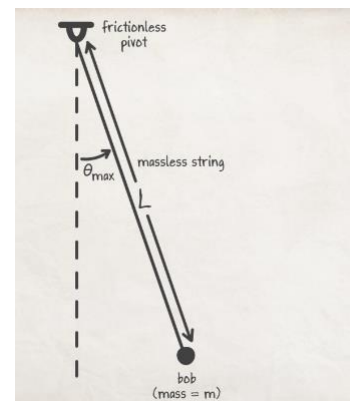
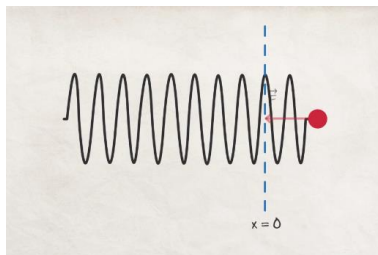
## What's up on the MyLab and Mastering?

- Notice that Homework 10 has been posted on MasteringPhysics. It is due Monday Nov.30 by 8:00am.
- Also, I have posted an item not for homework credits called "Videos and Practice for Chapter 10" which I recommend you check out.

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## Videos and Practice for Chapter 10

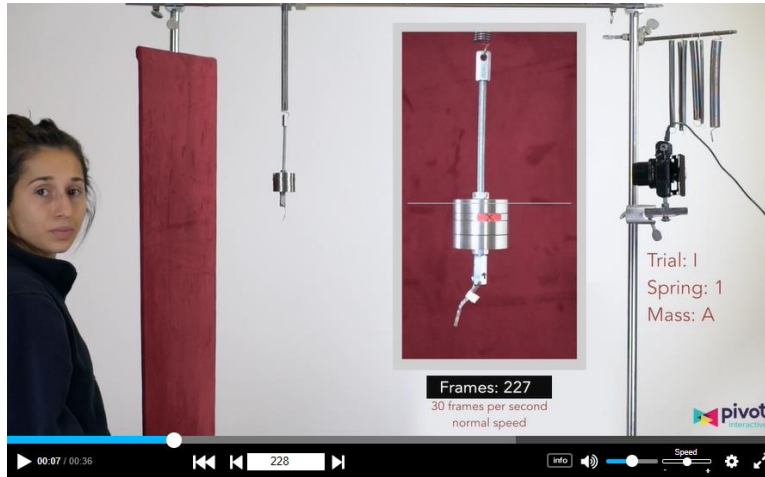
- There are 4 nice videos this week, all of which are animations
- **Mass on a Spring:** Conceptual + Quantitative
- **Pendulum:** Conceptual + Quantitative
- I really recommend you check these out!



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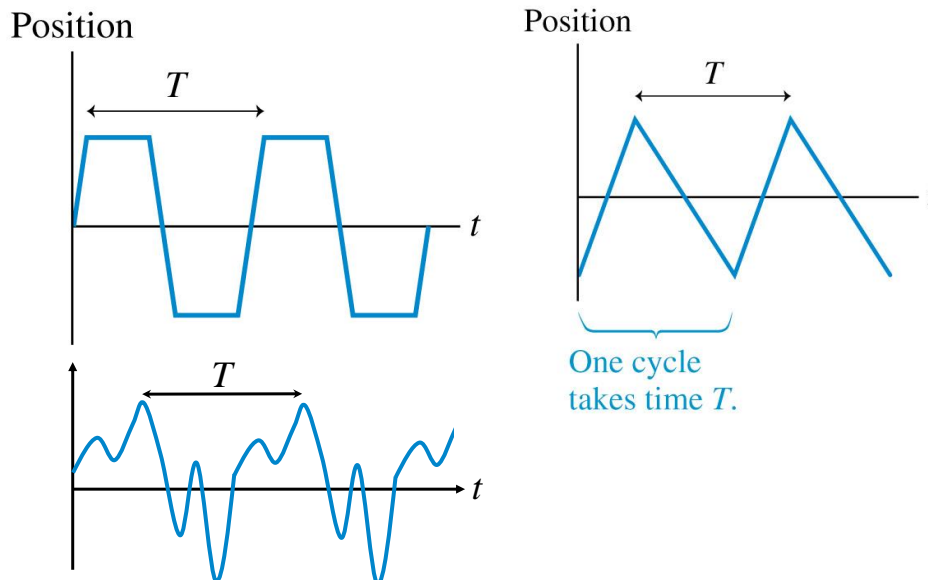
# Videos and Practice for Chapter 10

- There is also a fun video experiment you can try on your own.. She cuts the string and you measure things about the motion.



7

Some vibrations are **not** sinusoidal:



8

Video with sound



9

## Period and Frequency

- The time to complete one full cycle, or one oscillation, is called the period,  $T$ .
  - The frequency,  $f$ , is the number of cycles per second.
- Frequency and period are related by

$$f = \frac{1}{T} \quad \text{or} \quad T = \frac{1}{f}$$

- The oscillation frequency  $f$  is measured in cycles per second, or Hertz.

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## Poll question

If we turn up the water flow on a Japanese tipping fountain, and **double the frequency**, which of the following statements about that system is true?



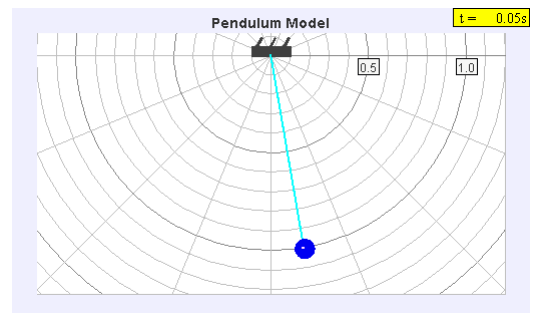
- A. The period is doubled.
- B. The period is reduced to one-half of what it was.
- C. The period is unchanged, but the fountain tips twice as far.
- D. The period is unchanged, but the fountain tips half as far.

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## Poll question

A pendulum has a period of 2.0 seconds (this is how long it takes to swing all the way back and forth, and back to where it started). What is its frequency?

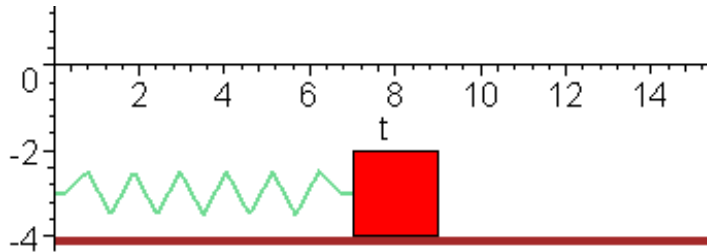
- A. 0.50 Hertz
- B. 1.0 Hertz
- C. 2.0 Hertz
- D. 4.0 Hertz



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## Thought Experiment

- A spring with a mass attached to it is stretched and released. When the spring returns to equilibrium, will the mass be moving?
- Answer: Yes! It is not **accelerating**, but it is **moving** at that moment. Inertia then carries it past equilibrium to the other side. After passing equilibrium, the acceleration is opposite the velocity, so it slows down, eventually turning around.



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## Vocabulary: “Equilibrium position”

**Equilibrium position (or just equilibrium)** The position at which a vibrating object resides when not disturbed. When resting at this position, the sum of the forces that other objects exert on it is zero. During vibrational motion the object passes back and forth through this position from two opposite directions.

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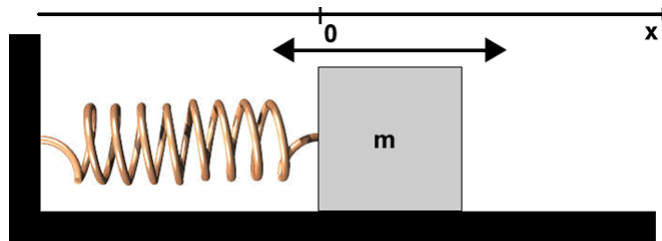
# Vocabulary: “Restoring force”

**Restoring force** When an object is displaced from equilibrium, some other object exerts a force with a component that always points opposite the direction of the vibrating object’s displacement from equilibrium. This force tends to restore the vibrating object back toward equilibrium.

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## “Mass on a Horizontal Spring”



The restoring force exerted on the mass by the spring:

$$F = -kx \quad (\text{Hooke's Law})$$

$$F = ma \quad (\text{Newton's Second Law})$$

Combine and solve  
for acceleration:  $a = -\frac{k}{m}x$

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## “Mass on a Horizontal Spring”

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

- What is acceleration? It is the rate of change of velocity.
- What is velocity? It is the rate of change of  $x$ .
- So, this equation is saying to us:  
“The slope of the slope of  $x$  equals a negative constant times  $x$ .”
- This is a very weird thing!
- It is certainly **NOT** constant acceleration, so everything you know about kinematics **won't work** for a mass on a spring.

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## Kinematics won't work.... or will it?

- Let's try **numerical integration**. This is a trick where you split up the motion into many segments, each over a small time  $\Delta t$  in which things that are not constant are *almost* constant.
- If acceleration is *almost* constant of a small time,  $\Delta t$ , then you can estimate the new velocity after that small time with the kinematics equation:  
$$v_f \approx v_i + a \Delta t.$$
- If velocity is *almost* constant of a small time,  $\Delta t$ , then you can estimate the new position after that small time with the constant velocity equation:  
$$x_f \approx x_i + v \Delta t.$$
- Now that you have a new value of  $x$ , compute a new value of  $a$ , etc.
- This can be done with an Excel spreadsheet! Let's do it!

[\[Go to Google Sheets\]](#)

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# Google Sheet

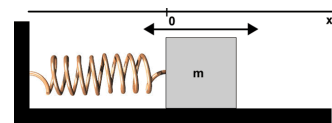
<https://docs.google.com/spreadsheets/d/1gaZrFYz6GnrL7wPbiJFWwW721QLOFon1OrFI9bczlrM/edit?usp=sharing>

	A	B	C	D	E	F
1	Time [s]	x [m]	v [m/s]	a=-k/m	Constants (Input numbers in Pink):	
2					time-step [s]:	
3					k [N/m]:	
4					m [kg]:	
5					Computed:	tf=ti+dt
6						xf=xi+(vi*dt)
7						vf=vi+(ai*dt)
8						
9						
10						

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## “Mass on a Horizontal Spring”

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



- I’m here to tell you that a lot of very brainy calculus people tried to solve the equation above, but in the end you just have to guess! The guess (greatly inspired by that Excel spreadsheet) is:

$$x = A\cos\left(\frac{2\pi}{T}t\right)$$

- Notice that  $x = +A$  at  $t = 0$ . If an object is at  $x = 0$  at  $t = 0$ , you can either adjust the  $\cos$  function by adding  $-(\pi/2)$  or use the sine function:

$$x = A\sin\left(\frac{2\pi}{T}t\right)$$

20

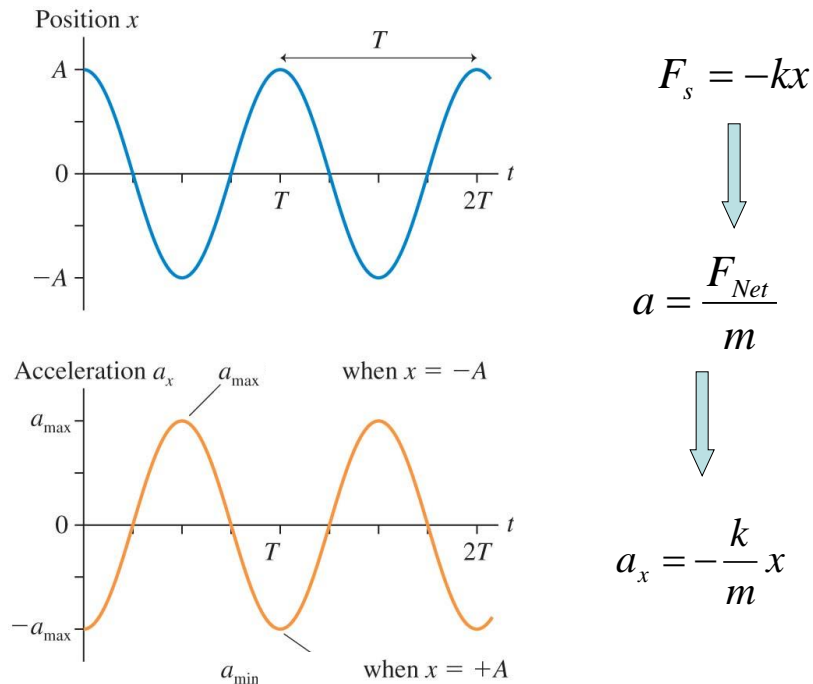
# Vocabulary: “Simple harmonic motion”

- Simple harmonic motion (SHM) is motion that can be described by the following equation:

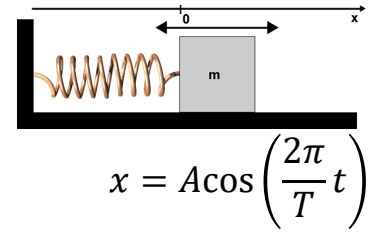
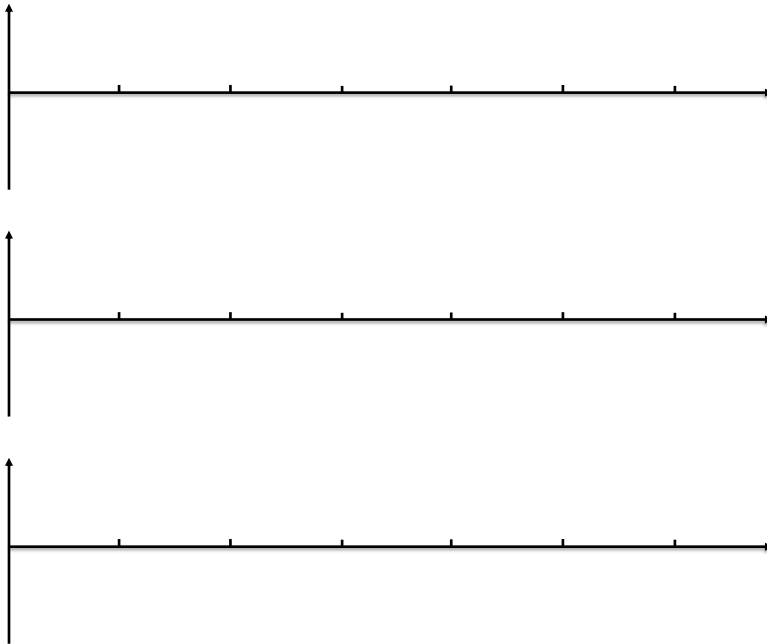
$$x = A \cos\left(\frac{2\pi}{T}t\right)$$

- It is a mathematical model of motion.

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22



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## S.H.M. notes.

- The period,  $T$ , is set by the properties of the system. In the case of a mass  $m$  attached to a spring of spring-constant  $k$ , the period is always

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

- $A$  is set by the initial conditions:  $x_0$  (initial position) and  $v_0$  (initial velocity).

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Poll Question

$$x = A \cos\left(\frac{2\pi}{T}t\right)$$

Which of the two constants ( $A$  and  $T$ ) in the description of simple harmonic motion is determined by the initial position and velocity of the mass?

- A. only the amplitude,  $A$
- B. only the period,  $T$
- C. both
- D. neither

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## Remember:

- The period,  $T$ , is set by the **properties of the system**. In the case of a mass  $m$  attached to a spring of spring-constant  $k$ , the period is always

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

- $A$  is set by the initial conditions:  $x_0$  (initial position) and  $v_0$  (initial velocity).

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## Before Class 30 on Friday

- Please continue reading Chapter 10:
  - 10.3 Dynamics of Simple Harmonic Motion
  - 10.4 Energy in Simple Harmonic Motion
  - 10.5 The Simple Pendulum
- 
- Plan to meet up with your Practical Pod during Friday's class – you should be able to turn on your microphone in order to participate in the TeamUp Quiz Module 5 Ch.10.
  - If you cannot do the TeamUp quiz during class, it can be done either with your pod or on your own at any time over the weekend.