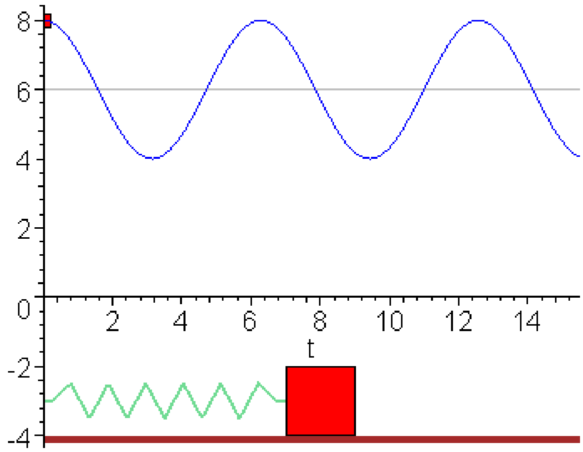
PHY131H1F - Class 29



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

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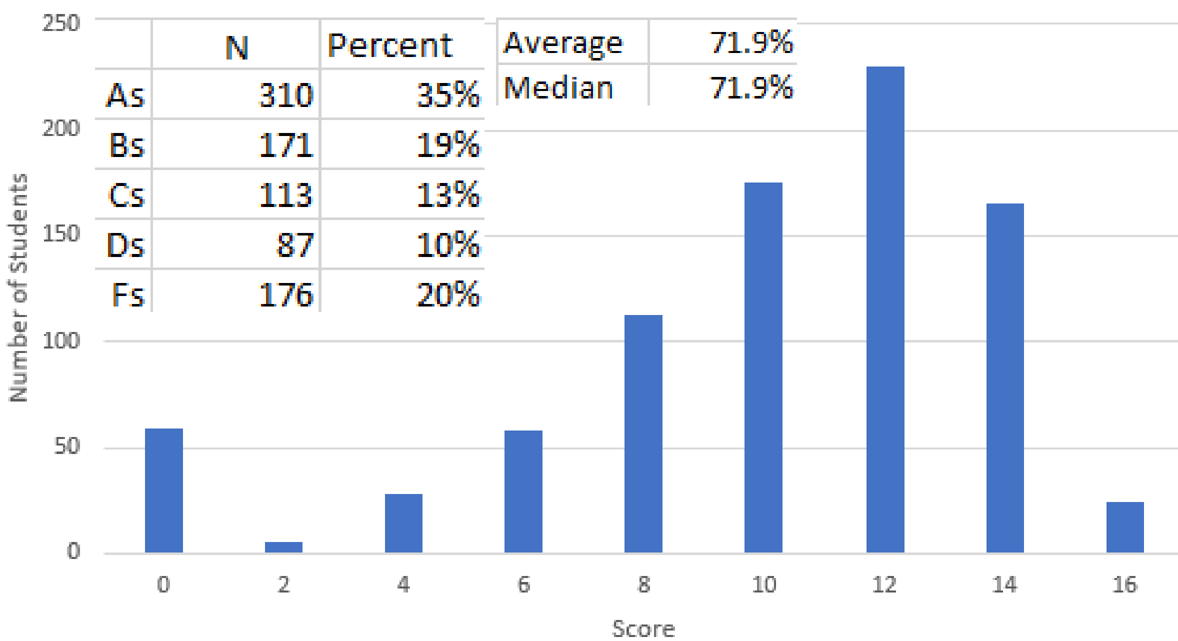
PHY131H1F Fall 2020 Midterm Assessment 4



	N	Percent
As	310	35%
Bs	171	19%
Cs	113	13%
Ds	87	10%
Fs	176	20%

Average	71.9%
Median	71.9%

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Midterm Assessment 4 Marking is done

- Please have a look over the marking.
- I have posted a rubric detailing how the TAs determined your marks "Midterm 4 Written Solutions with Grading Instructions".
- For each problem, one TA marked the entire class. This TA was consistent and stuck very strictly to the 2+2+2+2 rubric. Part marks were deducted in the same way for every student in the class.
- If there is a mistake in your marking or the computation of your mark, I would like to fix it. I will remark your test. Simply send an email to phy131fall@physics.utoronto.ca letting me know there was a mistake, and letting me know that you request a remark. You must do this by Monday Nov. 30 by 11:59pm at the latest.
- The TAs have worked there 32 hours each, as per their CUPE contract, and are not able to remark the tests. I will remark the tests as per your requests by correcting any marking mistakes I see.

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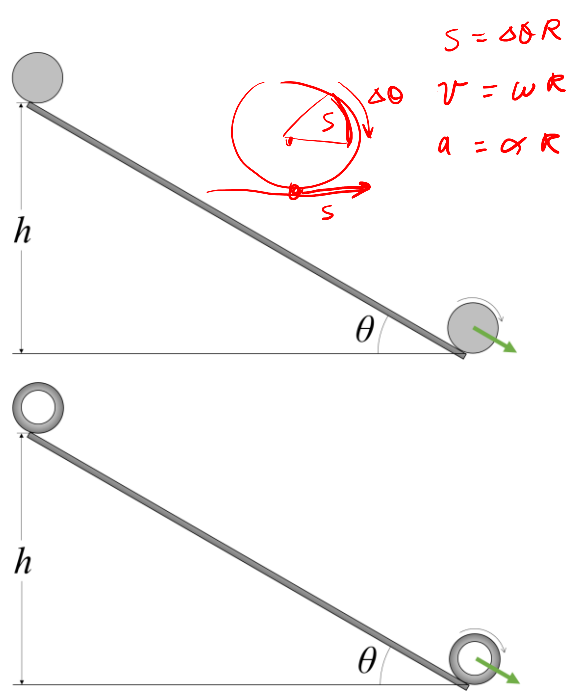
Ch.9 Poll Question

- 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



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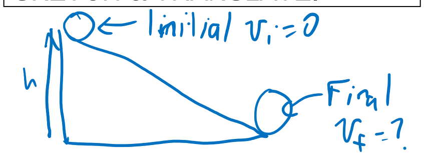
A solid disk (hoop) starts from rest and rolls without slipping down an incline. The change in height is *h*. What is its speed at the bottom?

SKETCH & TRANSLATE.



Radius, mass not given.

Rolling without slipping:

$v = \omega R$

$\omega_f = \frac{v_f}{R}$

Rotational Inertia $I = CmR^2$

Solid disk: $C = 1/2$

Hoop $C = 1$

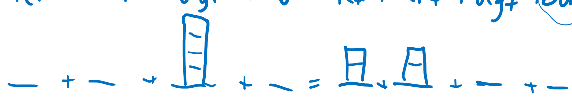
Static friction of stationary surface does no work.

SIMPLIFY & DIAGRAM

Define system = object + Earth.

Assume no external work done

$K_i + K_{ri} + U_{gi} + W = K_f + K_{rf} + U_{gf} + \Delta U_{int}$



REPRESENT MATHEMATICALLY

$$0 + 0 + mgh + 0 = \frac{1}{2} m v_f^2 + \frac{1}{2} I \omega_f^2 + 0 + 0$$

$$mgh = \frac{1}{2} m v_f^2 + \frac{1}{2} I \omega_f^2$$

plug in $I = CmR^2$, $\omega_f = \frac{v_f}{R}$

$$\cancel{m} gh = \frac{1}{2} \cancel{m} v_f^2 + \frac{1}{2} C \cancel{m} R^2 \left(\frac{v_f}{R}\right)^2$$

$$gh = \frac{v_f^2}{2} + \frac{C \cancel{R^2} v_f^2}{2 \cancel{R^2}}$$

SOLVE & EVALUATE

$$2gh = v_f^2 + C v_f^2 = (1 + C) v_f^2$$

$$v_f = \sqrt{\frac{2gh}{1+C}}$$

Solid Disk: $v_f = \sqrt{\frac{2gh}{1.5}}$ Hoop: $v_f = \sqrt{\frac{2gh}{2}}$

Disk goes faster

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…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.

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Mastering Physics

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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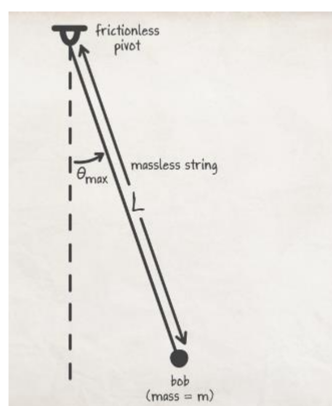
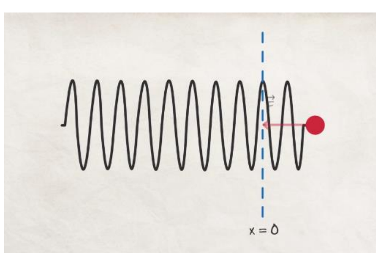
Mastering Physics

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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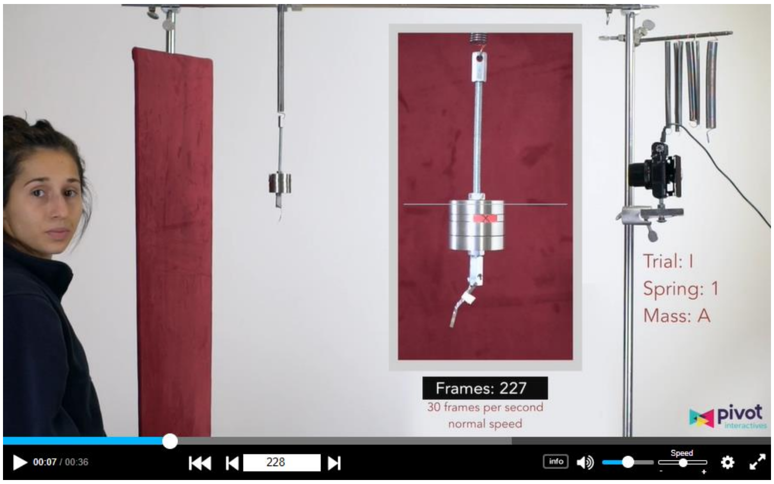
Mastering Physics
Videos and Practice for Chapter 10

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



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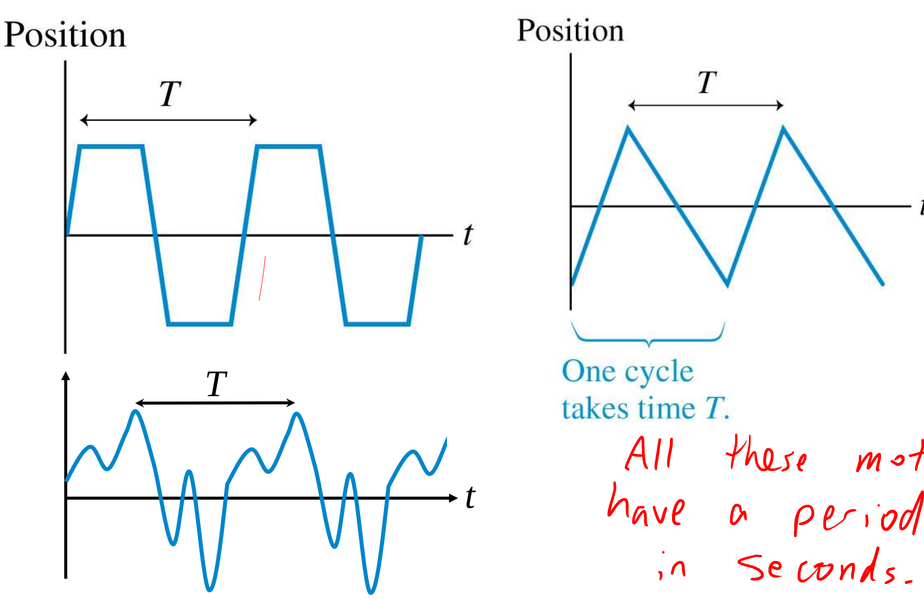
Some vibrations are ***not*** sinusoidal:



All these motions have a period, T. in seconds.

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https://youtu.be/xjuFXlFI2PA

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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

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

• The oscillation frequency f is measured in cycles per second, or Hertz. [Hz]

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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.

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

$f \uparrow, \ T \downarrow$

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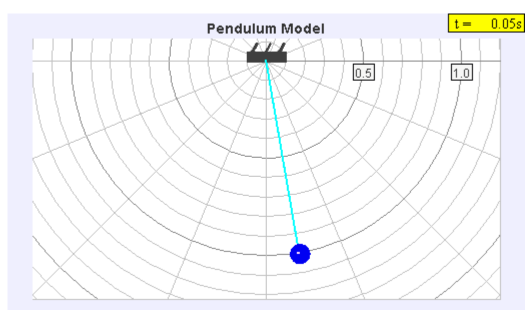
Poll question

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

$f = \frac{1}{2s} = 0.5\,Hz$



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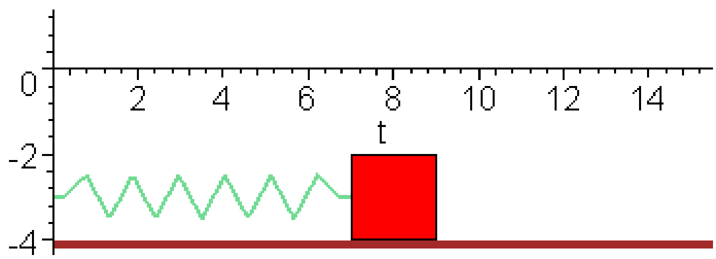
Thought Experiment

- 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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Thought Experiment

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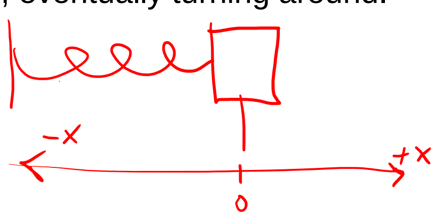
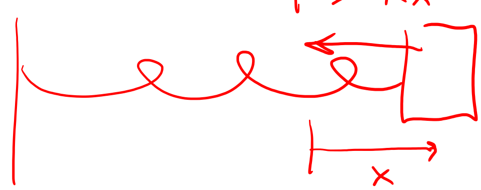
$F = -kx$





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

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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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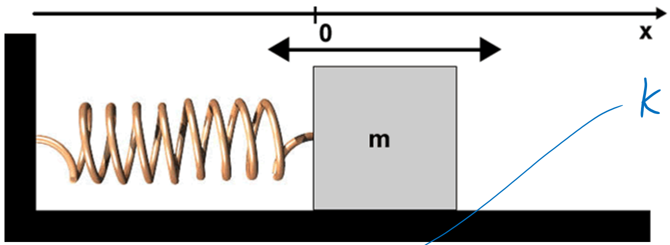
“Mass on a Horizontal Spring”



$k =$ spring constant
units: $\frac{N}{m}$

The restoring force exerted on the mass by the spring:

$\Sigma F_x = -k\,x$ (Hooke’s Law) $x = 0$ at equilibrium

$\Sigma F_x = m\,a$ (Newton’s Second Law) (No friction)

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

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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 Δt in which things that are not constant are *almost* constant.
- If acceleration is *almost* constant of a small time, Δt, then you can estimate the new velocity after that small time with the kinematics equation: $v_\mathrm{f} \approx v_\mathrm{i} + a\,\Delta t$.
- If velocity is *almost* constant of a small time, Δt, then you can estimate the new position after that small time with the constant velocity equation: $x_\mathrm{f} \approx x_\mathrm{i} + v\,\Delta t$.
- Now that you have a new value of x, compute a new value of a, etc.
- This can be done with Google Sheets spreadsheet! Let’s do it!

[Go to Google Sheets]

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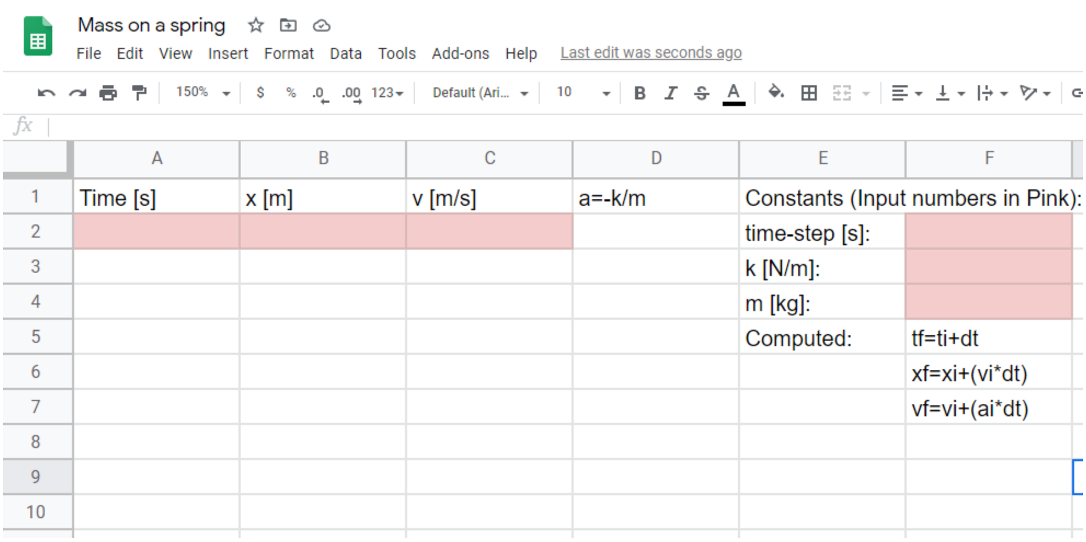
Google Sheet

https://docs.google.com/spreadsheets/d/1gaZrFYz6GnrL7wPbiJFWwW721QLOFon1OrFl9bczlrM/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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Google Sheet

https://docs.google.com/spreadsheets/d/1gaZrFYz6GnrL7wPbiJFWwW721QLOFon1OrFl9bczlrM/edit?usp=sharing

Mass on a spring

File Edit View Insert Format Data Tools Add-ons Help Last edit was seconds ago

fx Time [s]

	A	B	C	D	E	F
1	Time [s]	x [m]	v [m/s]	a=-kx/m	Constants (Input numbers in Pink):	
2	0	1	0	-1	time-step [s]:	0.01
3	0.01	1	-0.01	-1	k [N/m]:	1
4	0.02	0.9999	-0.02	-0.9999	m [kg]:	1
5	0.03	0.9997	-0.029999	-0.9997	Computed:	tf=ti+dt
6	0.04	0.99940001	-0.039996	-0.99940001		xf=xi+(vi*dt)
7	0.05	0.99900005	-0.0499900001	-0.99900005		vf=vi+(ai*dt)
8	0.06	0.99850015	-0.0599800006	-0.99850015		
9	0.07	0.99790035	-0.0699650021	-0.99790035		
10	0.08	0.9972007	-0.0799440056	-0.9972007		
11	0.09	0.9964012599	-0.0899160126	-0.9964012599		
12	0.1	0.9955020998	-0.0998800252	-0.9955020998		

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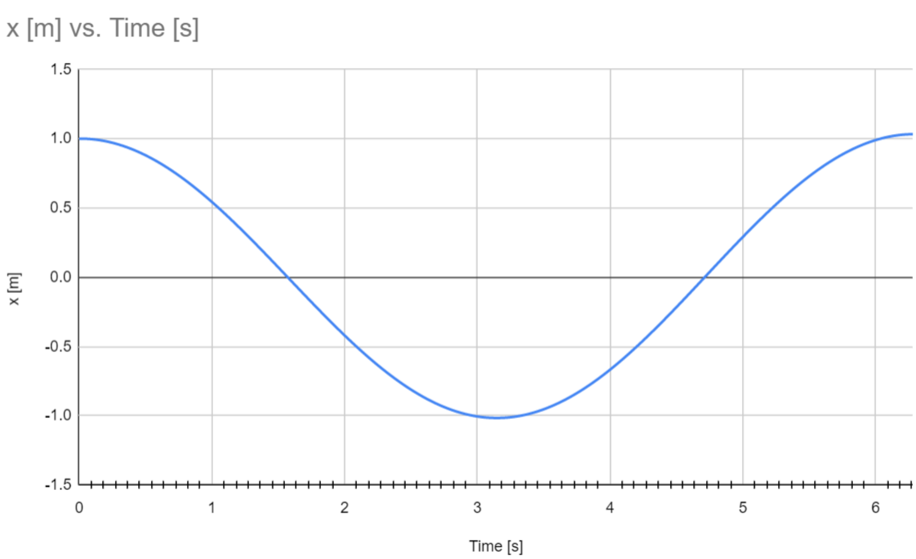
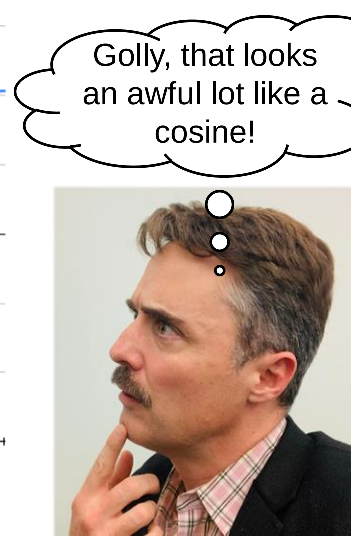
Google Sheet

https://docs.google.com/spreadsheets/d/1gaZrFYz6GnrL7wPbiJFWwW721QLOFon1OrFl9bczlrM/edit?usp=sharing





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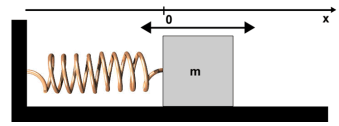
“Mass on a Horizontal Spring”



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

- 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:

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

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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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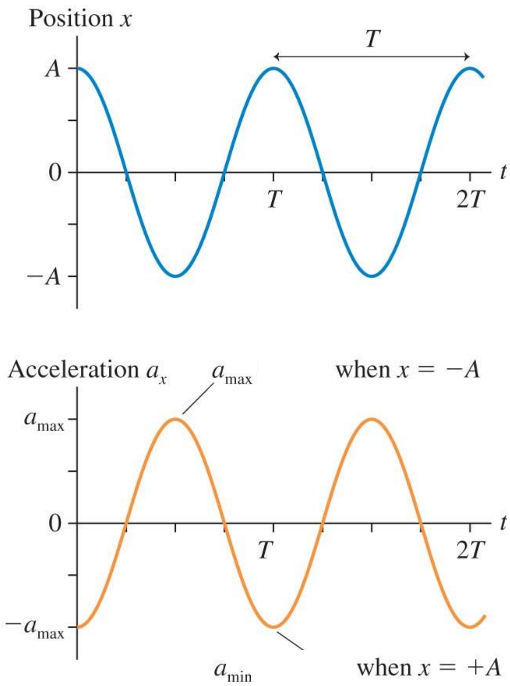

$$F_s = -kx$$

$$a = \frac{F_{Net}}{m}$$

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

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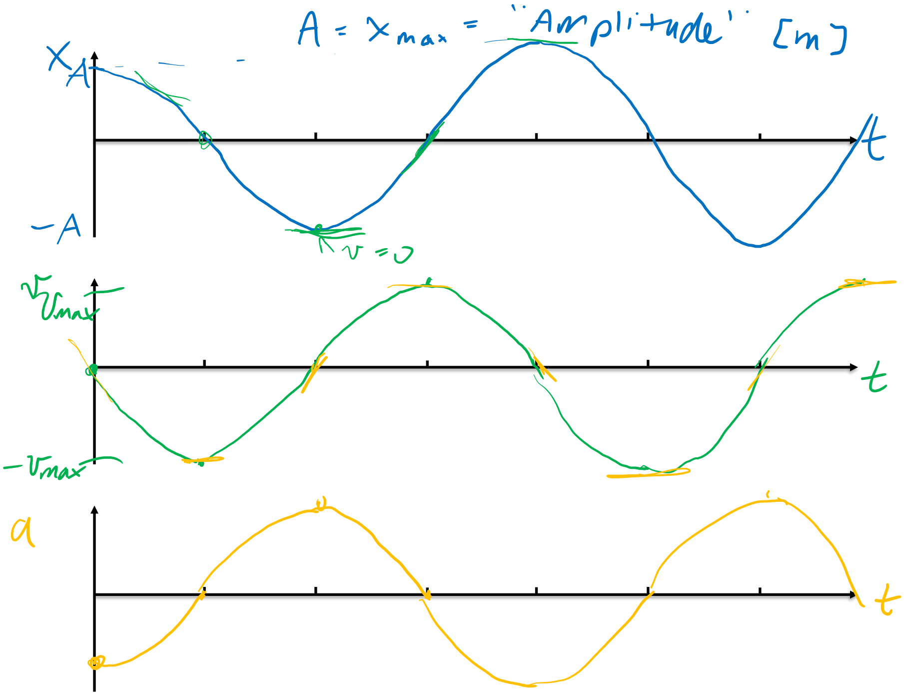
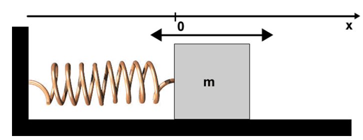
$A = x_{max} =$ "Amplitude" [m]





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

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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

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

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

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Poll Question

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

x = dependant variable

t = independant variable.

A, T are constants of motion.

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

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

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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.

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