

# PHY131H1F - Class 31



## Today:

10.6 Solving SHM Problems

10.7 Damped Vibrational Motion

10.8 Driven Vibrational Motion

From <http://www.cavatoyota.com/blog/what-are-shock-absorbers/> :  
To test your vehicle's shock absorbers, simply push down on the each corner of the vehicle and observe its bounce. The vehicle should bounce up and return to its center resting position. If it continues to bounce, the shock absorber **should be replaced**.

1

## Poll Question

Two pendula have the same length, but different mass. The force of gravity,  $F=mg$ , is larger for the larger mass. Which will have the longer period?



- A. the larger mass
- B. the smaller mass
- C. neither

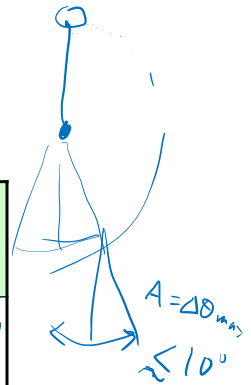
$$T = 2\pi \sqrt{\frac{L}{g}}$$

mass does not matter.

2

## Mass on Spring versus Pendulum

	Mass on a Spring	Pendulum
Condition for S.H.M.	Small oscillations (Hooke's Law is obeyed)	Small angles
Period	$T = 2\pi\sqrt{\frac{m}{k}}$	$T = 2\pi\sqrt{\frac{L}{g}}$



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<https://movember.com/m/14289186>



• Oct. 30, 2020



Nov. 30, 2020

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## Learning Assistant Alliance Email

LASSO

- You should have received an email recently from the Learning Assistance Alliance.
- They will be administering the Pre and Post diagnostic tests for this course, which you do online.
- This first test (FCI) is about physics, and the second (CLASS) is about your attitudes about science in general.
- These help us get to know you and also help us understand how much you will gain from this semester, especially in the new fully-online format.

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## Learning Assistant Alliance Email

- Both tests are optional, and your accuracy on the tests will not affect your mark in the course in any way.
- The deadline for the post-course tests is **Thursday Dec. 10**.
- To encourage you to do the tests, you will receive 1 homework credit for doing each of the two post-tests at (plus 2 from the start of the course), for a total possible of 4 homework credits.
- You get the credit for participation in the surveys; accuracy does not matter, but I encourage you to do your best.

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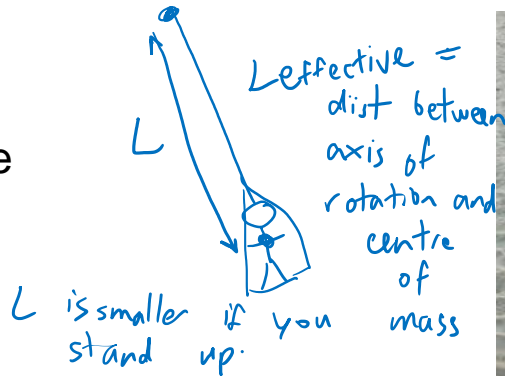
Poll Question

Assume S.H.M.

A person swings on a swing. When the person sits still, the swing oscillates back and forth with a certain period. If, instead, the person stands on the swing, the period of the swing oscillations is

$$T = 2\pi \sqrt{\frac{L}{g}}$$

- A. greater
- B. the same
- C. smaller**



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Poll Question

Assume S.H.M.

A grandfather clock, calibrated at sea level, is now operating in Calgary, Alberta, which is 1 km above sea level.

$$T = 2\pi \sqrt{\frac{L}{g}}$$

slight decrease in  $g$ .

This clock runs  $\Rightarrow$  slight increase in  $T$ .

- A. fast.
- B. slow.**
- C. normally, as it does at sea level.

tick . . . . . tick . . . . .



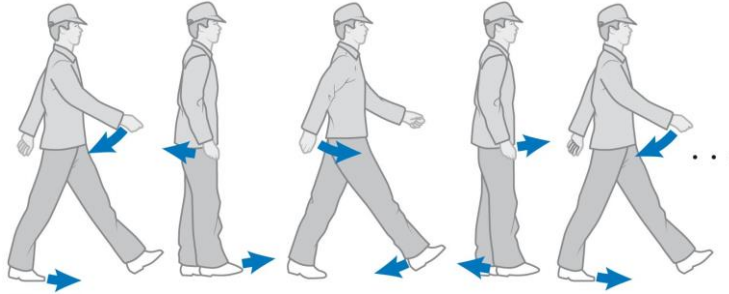
ticks

Image from [https://www.1-800-4clocks.com/Bulova-Vickery-Wall-Chimes-Clock\\_C4329\\_CUV](https://www.1-800-4clocks.com/Bulova-Vickery-Wall-Chimes-Clock_C4329_CUV)

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# Leg swinging frequency

- When you walk, your arms and legs swing back and forth. These motions repeat themselves.



- The back-and-forth motion of an object that passes through the same positions is an important feature of vibrational motion.

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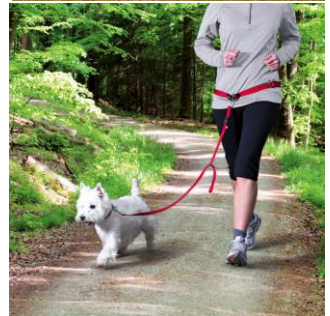
# Leg swinging frequency

- Your leg can be modeled as a simple pendulum, with length equal to the distance between your hip joint (rotation axis) and the centre of mass,  $L = 0.5$  m.
- In this case, the frequency is:

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

$$f \approx \frac{1}{2\pi} \sqrt{\frac{g}{L}} = \frac{1}{2\pi} \sqrt{\frac{9.8}{0.5}} = 0.7 \text{ Hertz}$$

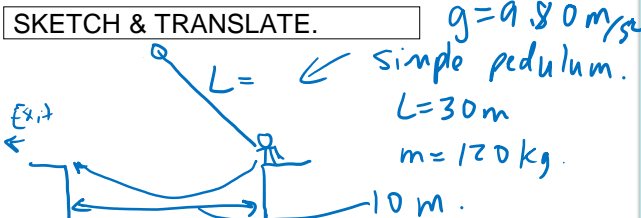
- Longer legs have lower swinging frequencies.
- Giraffes take fewer steps per second than humans because of their long legs.
- Small dogs take more steps per second than humans because of their short legs.



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Luke and Leia have a combined mass of 120 kg and both grasp a rope of length 30 m that is attached to a beam above them. The beam is half-way across a 10 m horizontal gap, and they want to swing across. If they start from rest and swing down and up, just reaching the other side, how long does this take?

SKETCH & TRANSLATE.



SIMPLIFY & DIAGRAM

Assume SHM.  
Back & forth  $\rightarrow$  one period.  
Across once will take  $\frac{T}{2}$ .

REPRESENT MATHEMATICALLY

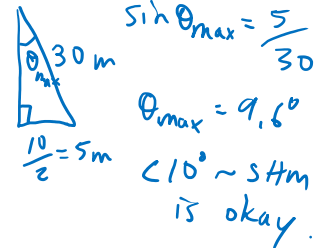
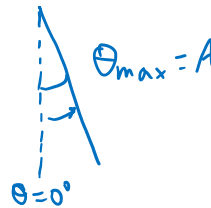
$$T = 2\pi \sqrt{\frac{L}{g}}$$

$$t = \frac{T}{2} = \pi \sqrt{\frac{L}{g}}$$

SOLVE & EVALUATE

$$t = 3.14159 \sqrt{\frac{30}{9.8}} = 5.5 \text{ s}$$

check



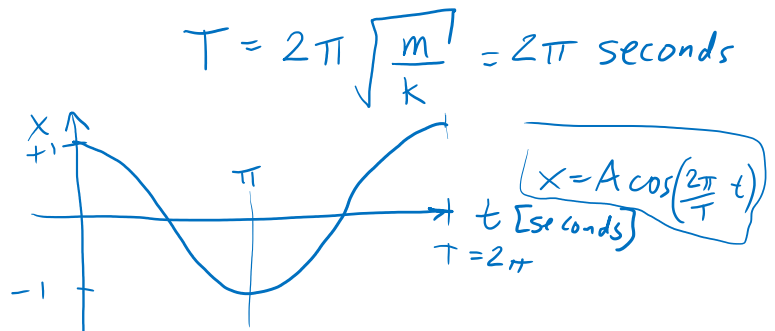
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## Poll Question

A 1.00 kg mass is attached to a horizontal spring with a spring constant of 1.00 N/m. When the mass is at  $x = 0$ , the spring is in equilibrium. The mass pulled to  $x = +1.00$  m, and then it is released from rest at time  $t = 0.00$  s.

At what time does the mass reach a position of  $x = -1.00$  m?

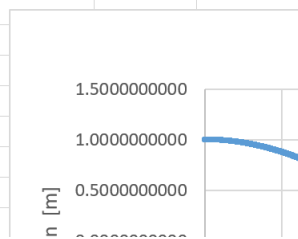
- A.  $t = 1.00$  s
- B.  $t = 2.00$  s
- C.  $t = 3.14$  s
- D.  $t = 4.00$  s
- E.  $t = 6.28$  s



[Excel Spreadsheet]

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	A	B	C	D	E	F	G	H
1	<b>Constants:</b>	time-step [s]:	0.00001	k [N/m]:	1	m [kg]:	1	
2	<b>(Input numbers in Pink)</b>							
3		Time [s]	x [m]	v [m/s]	a=-kx/m			
4	Initial:	0	1.0000000000	0	-1			
5	xf=xi+(vi*dt)	0.00001	1.0000000000	-0.00001	-1			
6	vf=vi+(ai*dt)	0.00002	0.9999999999	-0.00002	-1			
7		0.00003	0.9999999997	-3E-05	-1			
8		0.00004	0.9999999994	-4E-05	-0.9999999999			
9		0.00005	0.9999999990	-5E-05	-0.9999999999			
314157		3.14153	-1.0000157058	-6.3E-05	1.000015706			
314158		3.14154	-1.0000157064	-5.3E-05	1.000015706			
314159		3.14155	-1.0000157070	-4.3E-05	1.000015707			
314160		3.14156	-1.0000157074	-3.3E-05	1.000015707			
314161		3.14157	-1.0000157077	-2.3E-05	1.000015708			
314162		3.14158	-1.0000157079	-1.3E-05	1.000015708			
314163		3.14159	-1.0000157081	-2.7E-06	1.000015708			
314164		3.1416	-1.0000157081	7.3E-06	1.000015708			
314165		3.14161	-1.0000157080	1.7E-05	1.000015708			
314166		3.14162	-1.0000157078	2.7E-05	1.000015708			
314167		3.14163	-1.0000157076	3.7E-05	1.000015708			
314168		3.14164	-1.0000157072	4.7E-05	1.000015707			



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## Simple Harmonic Motion (SHM)

- If the net force on an object is a linear restoring force (ie a mass on a spring, or a pendulum with small oscillations), then the position as a function of time is related to cosine:

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

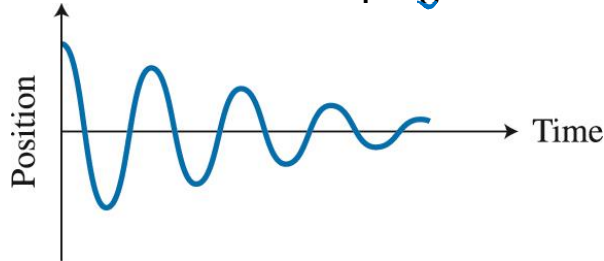


- Cosine is a function that goes forever, but in real life, due to friction or drag, all oscillations eventually slow down.

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# Damping

- The phenomenon of decreasing vibration amplitude and increasing period is called damping.

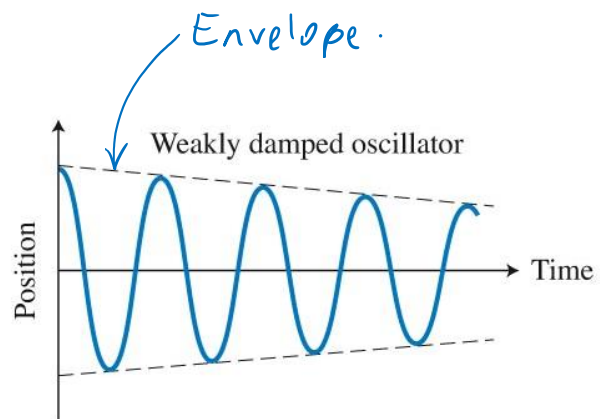


- Damping is a useful aspect of the design of vehicles and bridges.

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## Three Classes of Damping

1. A **weakly damped** system continues to vibrate for many periods.



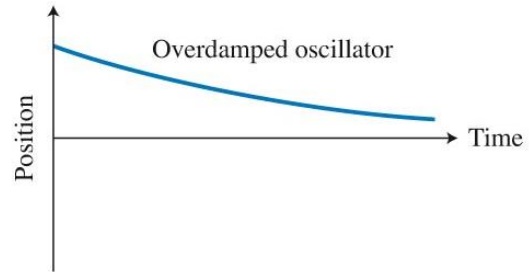
Envelope is a steadily decreasing function which decreases the amplitude.

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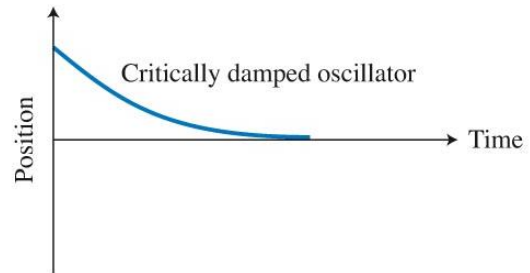


## Three Classes of Damping

2. In an **overdamped** system, the vibrating system takes a long time to return to the equilibrium position, if it ever does.



3. In a **critically damped** system, the vibrating object returns to equilibrium in the shortest time possible.



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## Damped Vibrations

- A 0.5 kg cart is attached to a horizontal spring, the other end of which is attached to a fixed bumper. The spring constant is  $150 \text{ N/m}$ . The cart is pulled to the side and released from rest when the spring has been stretched by  $0.035 \text{ m}$ . How much mechanical energy is converted to internal energy before the cart stops oscillating?

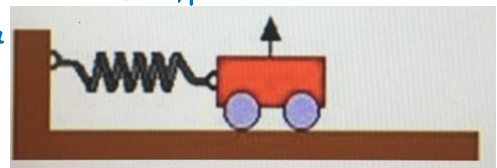
- A. 0.09 Joules  
 B. 0.11 Joules  
 C. 0.9 Joules  
 D. 1.1 Joules  
 E. 9 Joules

Idea: All initial energy is dissipated.

$$E = \frac{1}{2}kA^2 \text{ or } \frac{1}{2}m\omega_{\text{max}}^2$$

$$= \frac{1}{2}(150)(0.035)^2$$

$$= 0.091875 \text{ J}$$



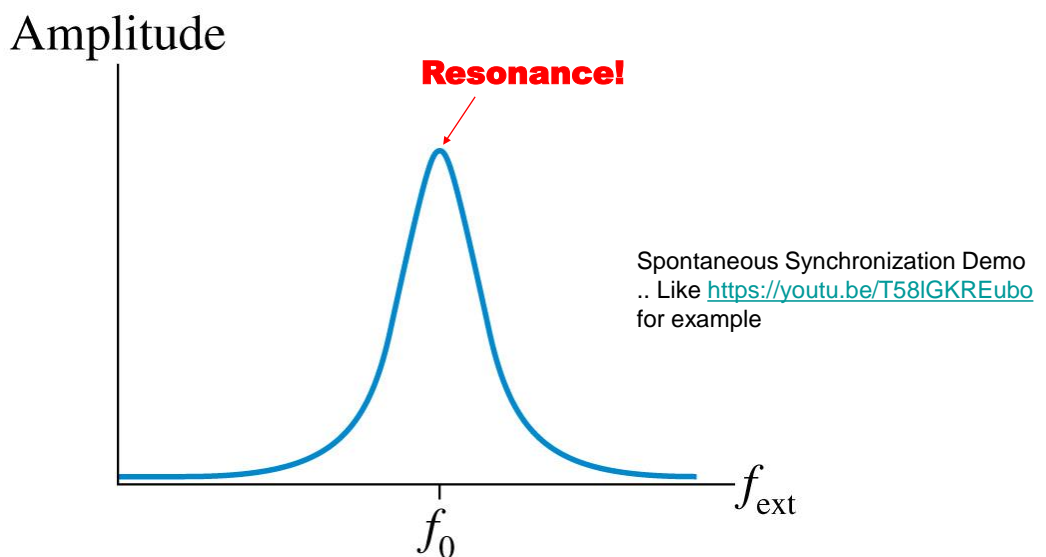
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## Driven Oscillations and Resonance

- Consider an oscillating system that, when left to itself, oscillates at a frequency  $f_0$ . We call this the **natural frequency** of the oscillator.
- Suppose that this system is subjected to a *periodic* external force of frequency  $f_{\text{ext}}$ . This frequency is called the **driving frequency**. Driven systems oscillate at  $f_{\text{ext}}$ .
- The amplitude of oscillations is generally not very high if  $f_{\text{ext}}$  differs much from  $f_0$ .
- As  $f_{\text{ext}}$  gets closer and closer to  $f_0$ , the amplitude of the oscillation rises dramatically.

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## 14.8 Externally Driven Oscillations

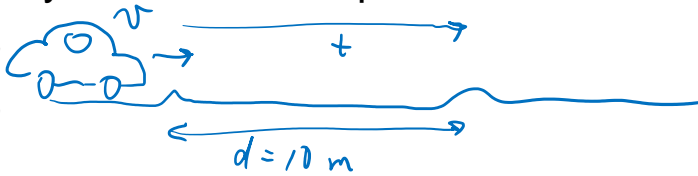


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# Feeling Road Vibrations in a Car

- If there are some equally spaced bumps on the road, every 10 m, and the natural frequency of the shock absorbers in your car is about 0.90 Hz, at what driving speed will you feel the bumps the most?

- A. 0.9 m/s
- B. 1.1 m/s
- C. 9 m/s**
- D. 11 m/s
- E. 90 m/s



For resonance, set  $t = T_0$

$$v = d \left( \frac{1}{T} \right) = d f = (10 \text{ m})(0.9 \text{ Hz}) = 9 \text{ m/s}$$

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## Energy transfer through resonance

- Resonance caused the collapse of the Tacoma Narrows Bridge in Washington only four months after its completion.

(a)



(b)



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## Midterm Assessment #5

- Each online half-hour assessment is worth between 10% and 12.5% of your mark in this course.
- The lowest of five assessment scores will be dropped.
- The assessment will become available on Quercus to start at 8:10pm tomorrow evening, Toronto time (ie 32 hours from right now)
- If you are registered for the alternate sitting, then you do the whole thing exactly 2 hours later.
- If you miss the assessment, you get a zero.

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## Midterm Assessment #5

- The assessment is "open book"; allowed aids include your course notes, the textbook, videos, google-searches for static web-pages, a calculator, Excel, Python, etc.
- You must work on the assessment **individually**.
- No group work or chats with other students are allowed during the assessment.
- Once you start there will be a 30-minute timer
- The assessment ends when your personal 30-minute timer elapses, or 8:45pm, whichever comes *first*.

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## Midterm Assessment #5

- You will see one question at a time, in a random order.
- You must submit each answer by clicking **Next** in order to see the next question; you will **not** have the ability to go back change any answer after it has been submitted.
- After completing all 10 questions you must click **Submit Quiz** before the time has ended.
- You **will** need a calculator, or Excel or something to do these. You should have pencil and paper ready for rough work.

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## Midterm Assessment #5: NEW FEATURE

- Tomorrow, every question will start with a time estimate, which is between 1 and 5 minutes, depending on the amount of work involved.
- 2 questions are 1 minute each.
- 4 questions are 2 minutes each.
- 2 questions are 3 minutes each.
- One question is 4 minutes and one question is 5.
- The sum of the time estimates for all 10 questions is 25 minutes, so, if you complete every question in the suggested amount of time, you will have 5 minutes to spare at the end.
- I will also include such estimates for the final assessment Dec.17.

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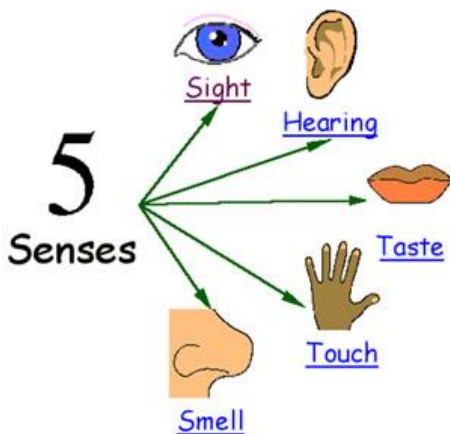
## Midterm Assessment #5

- All questions are Multiple Choice, marked automatically.
- Material will cover mostly questions and problems from Chapters 9 and 10 from Etkina. Chapters 2-8 are also important to remember, but are not specifically tested in this assessment.
- There will be at least one question based on your work in Practicals 4a and b.

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## Next up: Chapter 11 **Mechanical Waves**

- If you haven't done it, please check your utoronto email, respond to the course\_evaluations email and evaluate this course!



- Something to think about: Two of the five senses depend on **waves** in order to work: which two?

Image from <http://reger.weebly.com/the-five-senses.html>

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