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

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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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- Oct. 30, 2020

Nov. 30, 2020

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Poll Question

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

A. greater
B. the same
C. smaller

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Poll Question

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

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

Image from https://www.1-800-4clocks.com/Bulova-Vickery-Wall-Chimes-Clock_C4329_CUV

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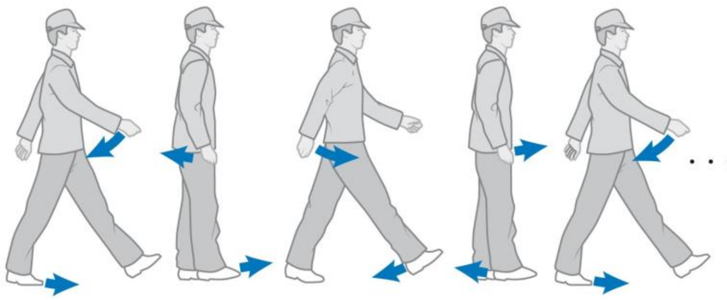
Leg swinging frequency

- 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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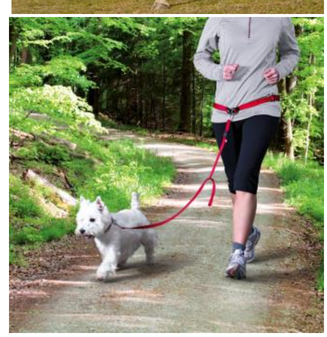
Leg swinging frequency



- 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:

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

- 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

REPRESENT MATHEMATICALLY

SOLVE & EVALUATE

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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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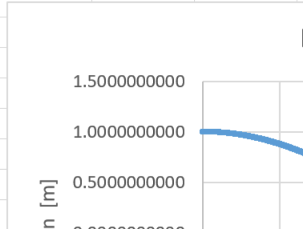
	A	B	C	D	E	F	G	H
1	**Constants:**	time-step [s]:	0.00001	k [N/m]:	1	m [kg]:	1	
2	**(Input numbers in Pink)**							
3		Time [s]	x [m]	v [m/s]	a=-kx/m			
4	Initial:	0	1.0000000000	0	-1			
5	xf=xi+(vi*dt)	0.00001	1.0000000000	-0.00001	-1			
6	vf=vi+(ai*dt)	0.00002	0.9999999999	-0.00002	-1			
7		0.00003	0.9999999997	-3E-05	-1			
8		0.00004	0.9999999994	-4E-05	-0.999999999			
9		0.00005	0.9999999990	-5E-05	-0.999999999			
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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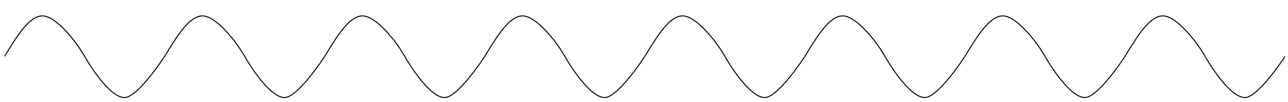
Simple Harmonic Motion (SHM)

- 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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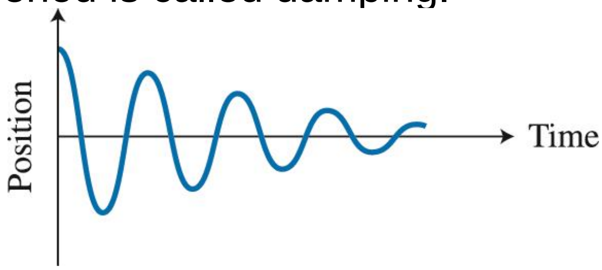
Damping

- 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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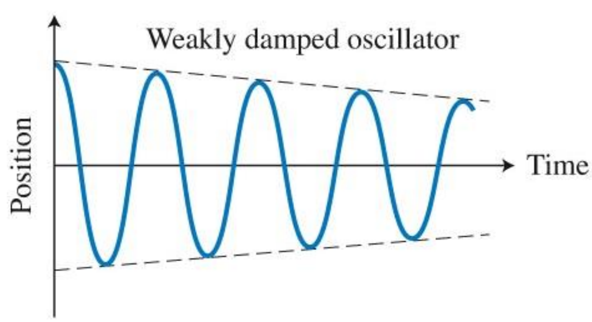
Three Classes of Damping

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



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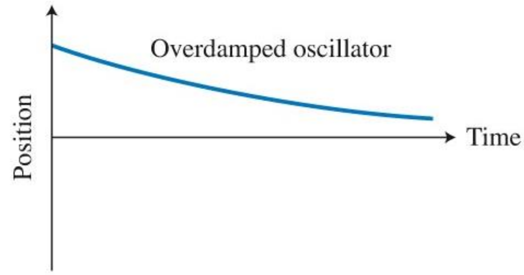
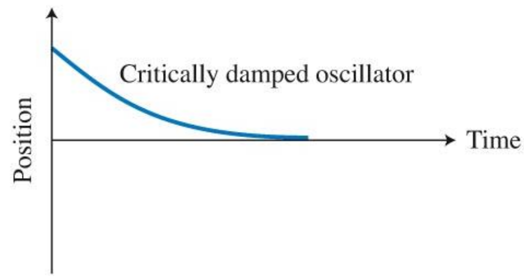
Three Classes of Damping

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.



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 N/m. The cart is pulled to the side and released from rest when the spring has been stretched by 0.035 m. How much mechanical energy is converted to internal energy before the cart stops oscillating?

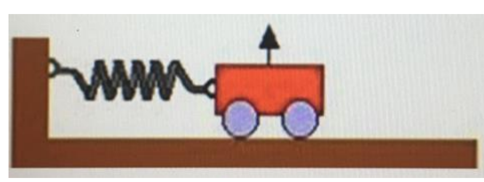
A. 0.09 Joules

B. 0.11 Joules

C. 0.9 Joules

D. 1.1 Joules

E. 9 Joules



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_{ext}. This frequency is called the **driving frequency**. Driven systems oscillate at f_{ext}.

• The amplitude of oscillations is generally not very high if f_{ext} differs much from f_0.

• As f_{ext} gets closer and closer to f_0, the amplitude of the oscillation rises dramatically.

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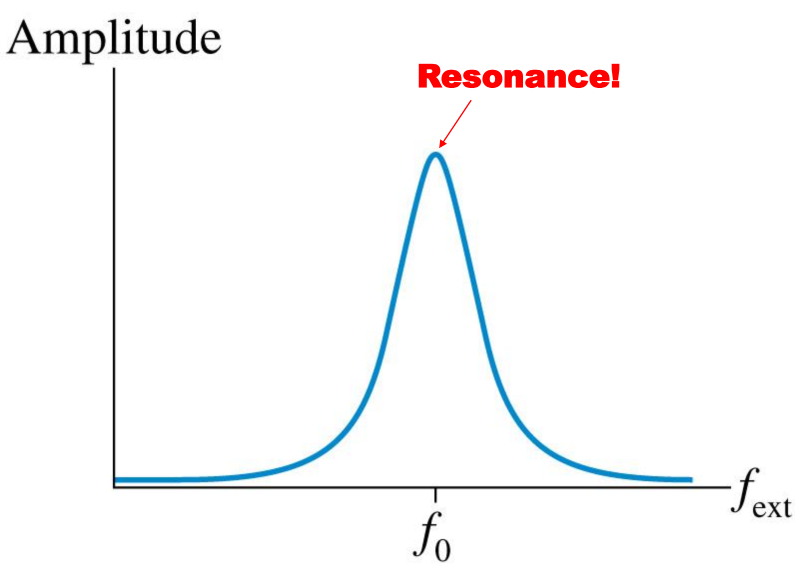
14.8 Externally Driven Oscillations



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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

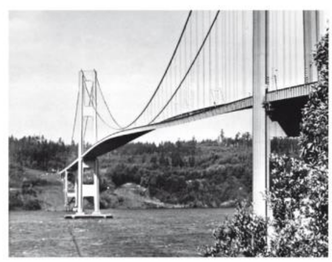
D. 11 m/s

E. 90 m/s

Energy transfer through resonance

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

(a)



(b)

Midterm Assessment #5

- Each online half-hour assessement 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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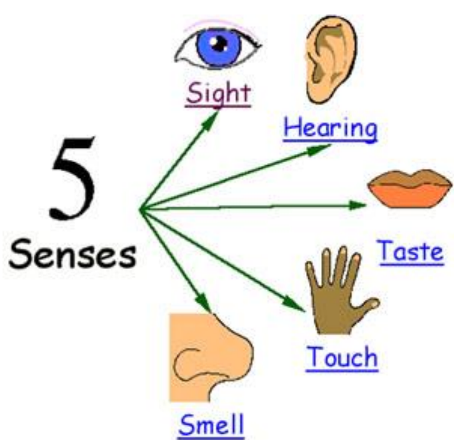
Next up: Chapter 11 **Mechanical Waves**

- 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://freger.weebly.com/the-five-senses.html

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