L 20 – Vibration, Waves and Sound-1 Resonance The pendulum Springs Harmonic motion Mechanical waves Sound waves Sound waves Musical instruments

Tacoma Narrows Bridge Collapse

- Over Puget Sound in Tacoma, WA
- Opened 1 July 1940, collapsed 7 Nov. 1940Puget sound known for very high winds, 40
- mph cross winds on Nov. 7
- Wind produced external periodic forcing in resonance with bridge's natural frequency
- Effect know as aerodynamic flutter
- Votrex street downstream produces periodic force on bridge at bridge's natural frequency —resonance phenomenon









A simple vibrating system: The Pendulum

- · Used by Galileo to measure time
- It is a good timekeeping device because the time for a complete cycle (its period) does not depend on its mass, and is approximately independent of its where it starts (its amplitude).



• The pendulum is an example of a harmonic oscillator- a system which repeats its motion over and over again







- the restoring force is the key to understanding systems that oscillate or repeat a motion over and over.
- the restoring force always points in the direction to bring the object back to equilibrium (for a pendulum at the bottom)
- from A to B the restoring force accelerates the pendulum down
- from B to C it slows the pendulum down so that at point C it can turn around

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Simple harmonic oscillator

- if there are no drag forces (friction or air resistance) to interfere with the motion, the motion repeats itself forever → we call this a *simple harmonic oscillator*
- *harmonic* repeats at regular intervals
- The time over which the motion repeats is called the <u>period</u> of oscillation
- The number of times each second that the motion repeats is called the <u>frequency</u>

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It's the INERTIA!

- even though the restoring force is zero at the bottom of the pendulum swing, the ball is moving, and since it has inertia it keeps moving to the left
- as it moves from B to C, gravity slows it down (as it would any object that is moving up), until at C it momentarily comes to rest, then gravity pulls it down again

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Energy of a pendulum If there is no friction or air resistance, the total energy of the pendulum, E = KE + GPE is constant.					
	POSITION	ENERGY	COMMENTS		
	А	GPE	starting position at rest		
	$A \rightarrow B$	KE + GPE	falling and speeding up		
	В	KE	maximum speed		
	$B \rightarrow C$	KE + GPE	rising and slowing down		
	С	GPE	momentarily at rest		
	C→B	KE + GPE	falling and speeding up		
	В	KE	maximum speed		
	B→A	KE + GPE	rising and slowing down		
	А	GPE	momentarily at rest	13	
				15	















The period (T): time for one <i>complet</i> e cycle				
PENDULUM	MASS/SPRING			
$T_{pendulum} = 2\pi \sqrt{\frac{L}{g}}$ • L = length (m) • g = 10 m/s ² • does not depend on mass • for L = 1 m,	$T_{mass-spring} = 2\pi \sqrt{\frac{m}{k}}$ • m = mass in kg • k = spring constant in N/m			
$T \approx 2\pi \sqrt{\frac{1m}{10m/s^2}} \approx \frac{2\pi}{\sqrt{10}} \approx 2 s$	21			