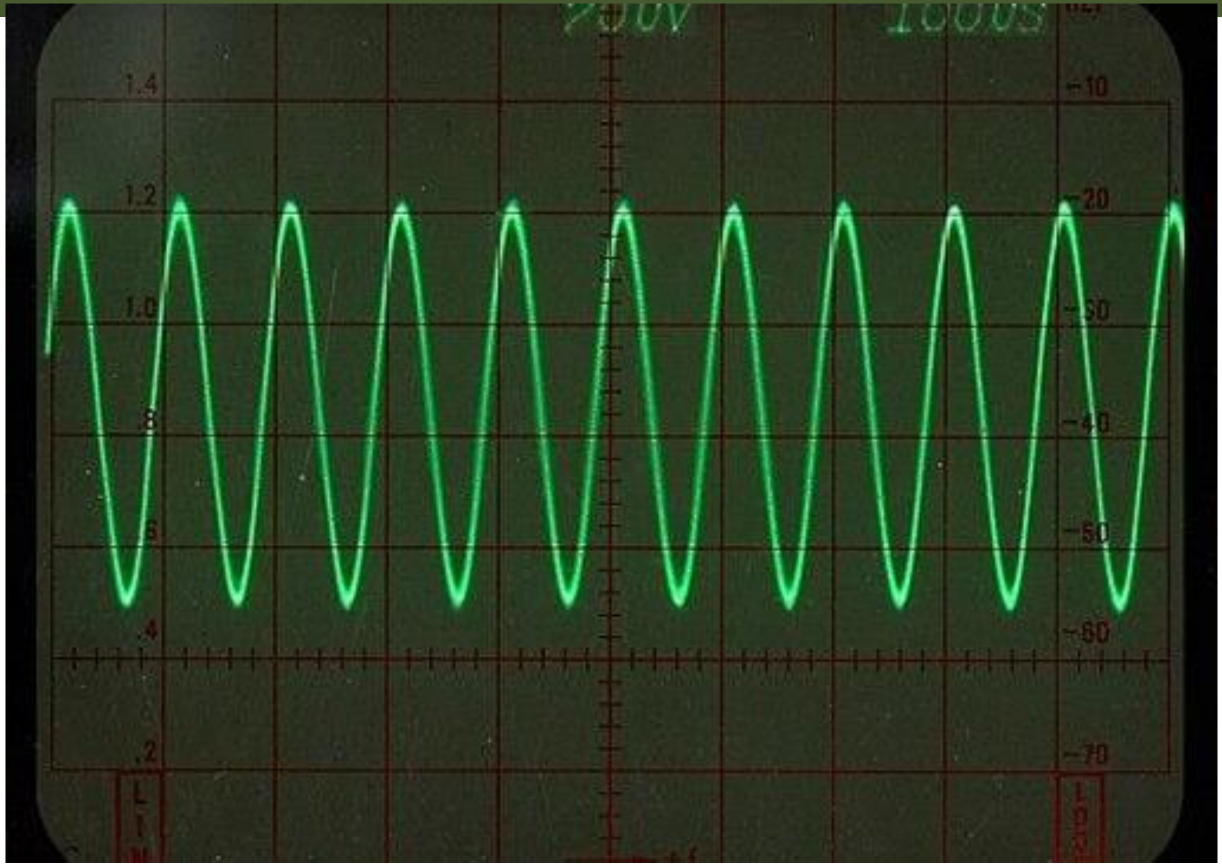


OSCILLATORY MOTION AND WAVES

NJ-OER TOPIC-16

Original Publication Year 2022

Funding Statement

This material was funded by the Fund for the Improvement of Postsecondary Education (FIPSE) of the U.S. Department of Education for the Open Textbooks Pilot grant awarded to Middlesex College (Edison, NJ) for the Open Textbook Collaborative.

Open Textbook Collaborative

The Open Textbook Collaborative. (OTC) project is a statewide project managed by Middlesex College along with assistance from Brookdale Community College, Ocean County College, Passaic County Community College, and Rowan University.

The project engages a consortium of New Jersey community colleges and Rowan University to develop open educational resources (OER) in career and technical education STEM courses.

The courses align to career pathways in New Jersey’s growth industries including health services, technology, energy, and global manufacturing and supply chain management as identified by the New Jersey Council of Community Colleges.

General Physics I

Moe Tabanli

Learning Outcomes

- Relate period, frequency and angular frequency for an oscillatory motion
- Distinguish between the motion parameters A,f,T,w and the dynamic properties such as mass, moment of inertia, spring coefficient, gravity etc.
- Calculate motion parameters from the dynamic properties
- Describe a simple harmonic oscillator equation
- Write the equation of motion using the motion parameters
- From a given equation of motion, estimate motion parameters and dynamic variables
- Explain the link between simple harmonic motion and waves.
- State characteristics of waves and standing waves
- Understand the role of wavelength in destructive and constructive interferences

Concepts

F= force
k= spring constant
x= displacement from equilibrium position
f = frequency
T= period
ω= angular frequency
A = Amplitude of displacement
θ= angular displacement
θ_{max}= Amplitude of a pendulum
ϕ= phase constant
m = mass
V_{max}= maximum velocity
a_{max}= maximum acceleration
λ = wavelength

Units

SI UNITS
Force is in Newtons
Frequency is in Hz
angular frequency is in rad/sec
Period is in seconds (s)
angular displacement is in radians
phase constant is in radians
Mass is in Kg
wavelength is in meters (m)
Amplitude is in meters (m)
Velocity is in m/s
Acceleration is in m/s^2

Formulas and Constants

$f = 1/T$

$f = 1/T$

$\omega = 2\pi f$ $2\pi f$

Springs

$F = -k(x-xo)$

$E = \frac{1}{2} k A^2$

$E = \frac{1}{2} m\, vmax^2$

$x = A \cos(\omega t)$ x-oscillation starting at A

$x = A \cos(\omega t+\phi)$

$\omega^2 = k/m$

Pendulum

$\theta = \theta max \cos(\omega t+\phi)$

$\omega^2 = g/L$ Simple Pendulum

$\omega^2 = mgR/I$ Physical Pendulum

Waves

$v = \lambda f = \lambda /T$

KEY STRATEGIES

f, T and ω are related, knowing one means knowing all $f = 1/T$ $\omega = 2\pi f$
Above equations applies to all Simple Harmonic Motion (SHM)

The equation that connects dynamic variables to kinematics are different for each system
$\omega^2 = k/m$ for spring $\omega^2 = k/m^2 = g/L$ for the simple pendulum

If the equation of motion is given, A, ω, ϕ can be found by matching the variables. Other unknowns can be calculated

$$x = 3.2 \cos(5t + 0.2)$$

$$x = A \cos(\omega t + \phi)$$

If A, ω, ϕ are given or can be calculated, equation of motion can be found by substituting
$\Phi = 0$ If the motion starts from $x_{max} = A$

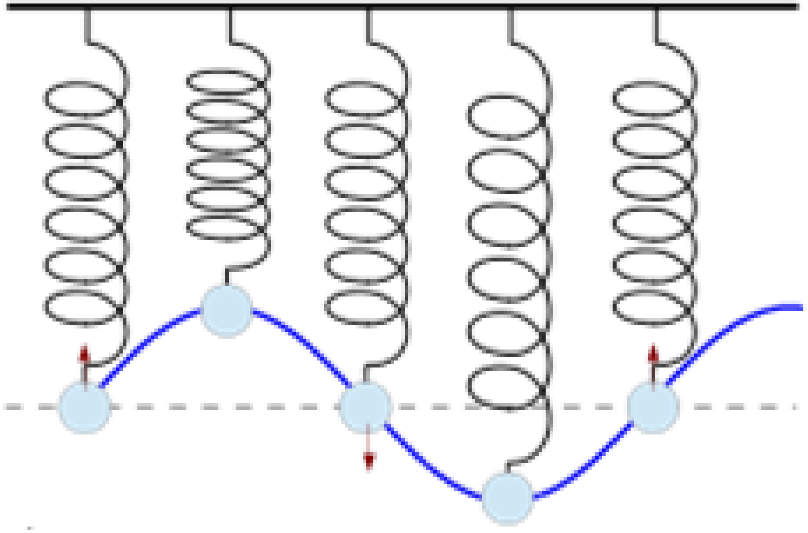
CLASSWORK FOR SHM OF A SPRING

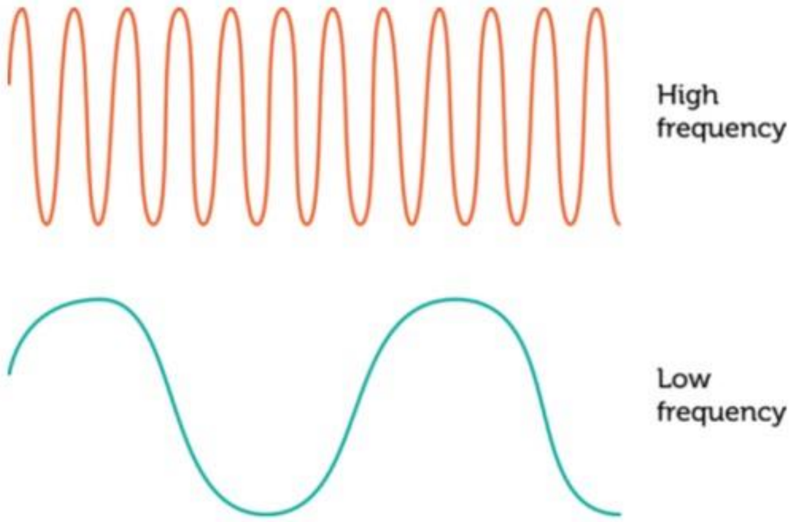
Mass "m" is oscillating on a spring with spring coefficient "k" along the x-axis with amplitude A. Complete the table below using the known values and equations

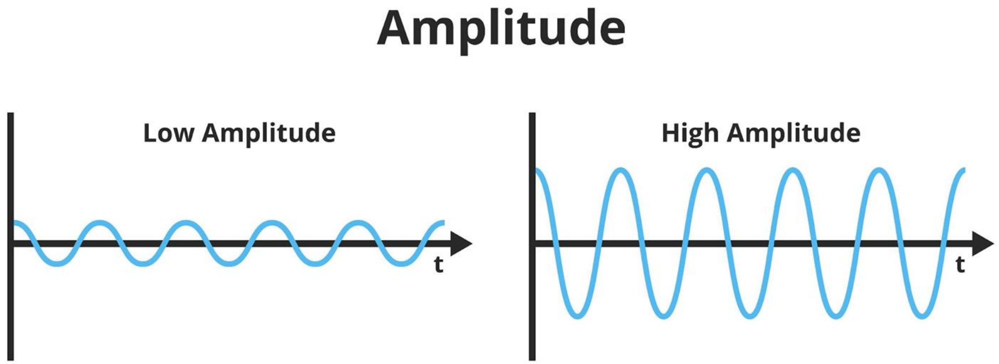
A Amplitude meters	f Frequency Hz	T Period s	w Angular Frequency radHZ	k Spring Coefficient N/m	m Mass kg	Energy Joules	Equation A cos(wt)
2.4	5.0			200			
					4		5 cos(7 t)
		5		20		40 J	
				9			3 cos(3.14 t)

x=Acos(w t) f=1/T   w=2pi f   w=sqrt(k/m) Energy=½ k A^2

GRAPHING SIMPLE HARMONIC MOTION

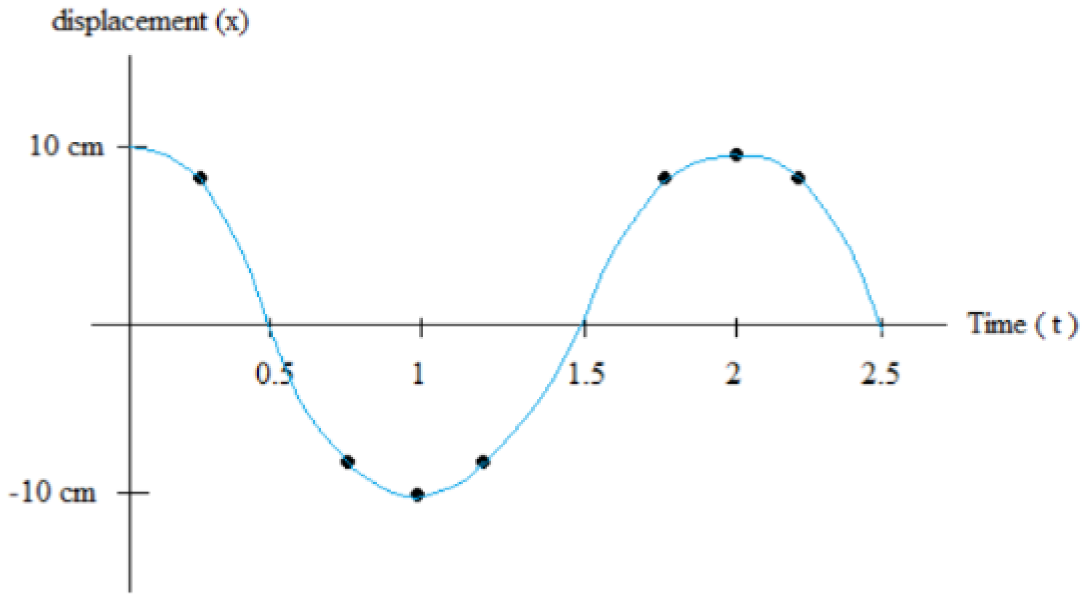






CLASSWORK ON GRAPHS

Q1)Determine the amplitude and the period of the simple harmonic motion on the graph



Q2) Graph a simple harmonic motion graph with amplitude of 2.2 m and frequency of 0.2 HZ

Q3) $y = 4.2 \cos(\pi t + \pi/4)$ is given. Graph the motion as y vs t.

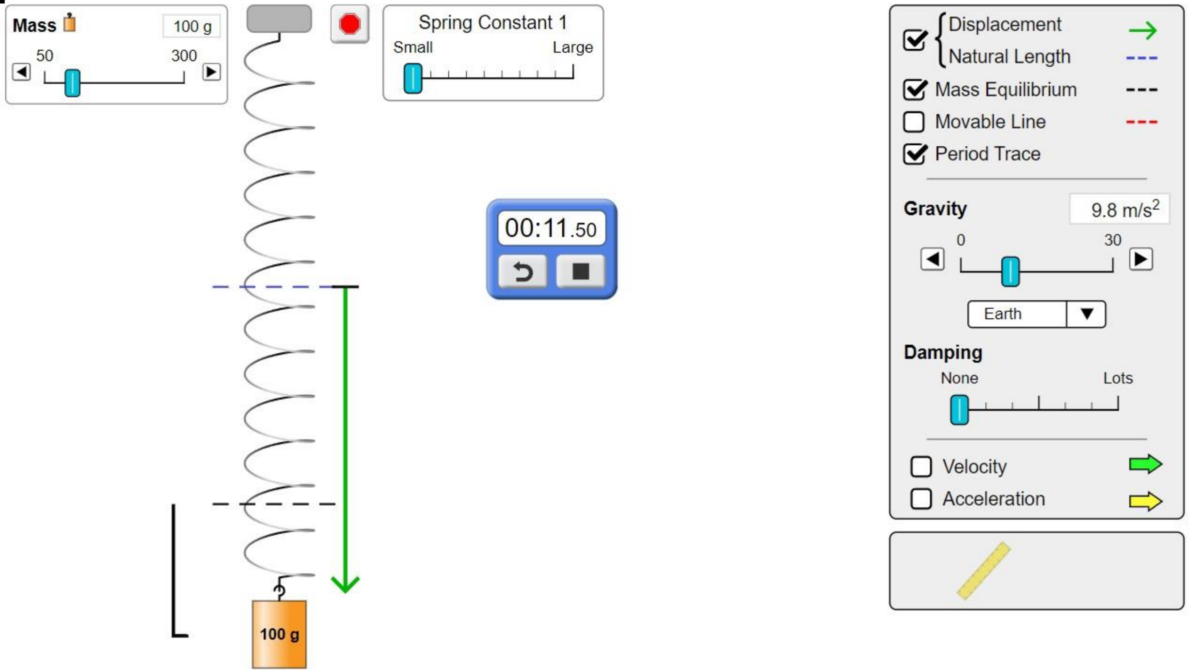
ACTIVITY OSCILLATIONS

Determine the spring coefficient by measuring the period. Go to the link below.
https://phet.colorado.edu/sims/html/masses-and-springs/latest/masses-and-springs_en.html
Reduce damping to zero from the toolbar at the right, click on period trace
Drag the timer from the bottom right. Attached the mass to the spring and pull it down.
Adjust your mass and spring constant using the slider tools at the top.
Start your timer. In order to increase accuracy, you must count ten oscillations and stop the timer. (App works better at slow motion.)
Divide the measured time to ten, this should give you your period "T".
Using the values for mass and period calculate the spring coefficient using the equation. $T^2 = 4\pi^2 m/K$ Change the spring coefficient and repeat the activity k $= 4\pi^2 m/T^2$

Mass (kg)	Spring Constant	Time for 10 Oscillation	Period T (s)	k (N/m)
0.100	small			
0.200	small			
0.050	medium			
0.300	large			

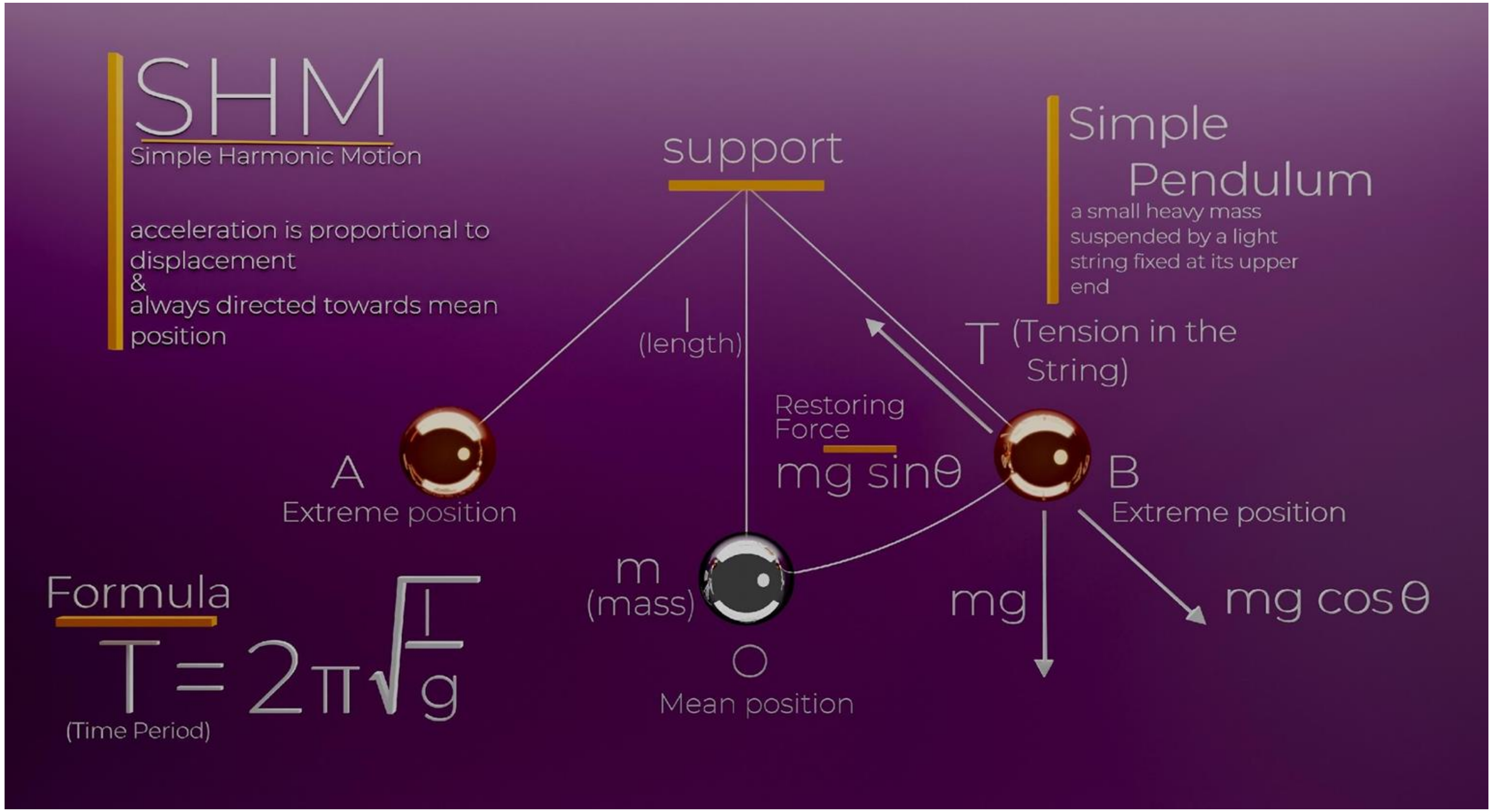
ACTIVITY OSCILLATION

Determine the spring coefficient by measuring the period for each of the case on the table using the PhET app https://phet.colorado.edu/sims/html/masses-and-springs/latest/masses-and-springs_en.html



Mass (kg)	Spring Constant	Time for 10 Oscillation	Period T (s)	k (N/m)
0.100	small			
0.200	small			
0.050	medium			
0.300	large			

SIMPLE PENDULUM



It is not advisable to use w for the simple pendulum. Because w can be used for angular speed which is a variable and angular frequency which is a constant.

CLASSWORK SIMPLE PENDULUM

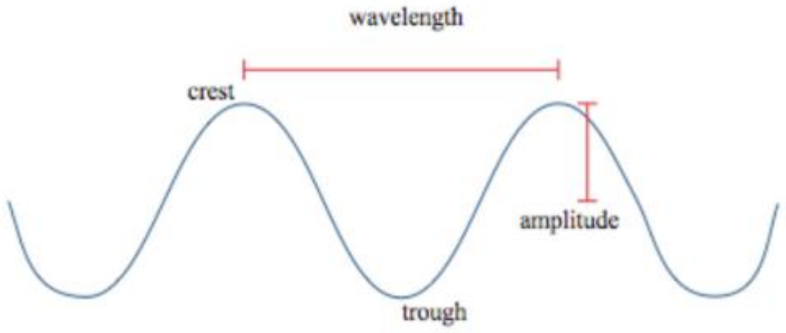
Mass "m" is attached to a string with length "L" and oscillating on a planet with gravitational constant g. Complete the table below using the known values and equations

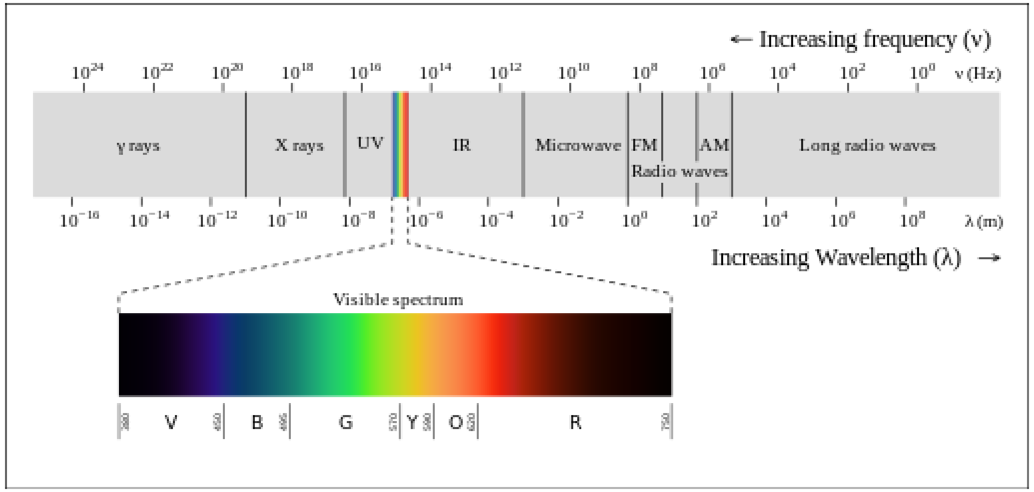
A Amplitude radians	f Frequency Hz	T Period s	Length meters	Gravity g m/s^2	Equation A cos ($2\pi f$ t)
0.4	5.0			9.8	
			1.0		5 cos(7 t)
0.2		5		20	
				9	3 cos(3.14 t)

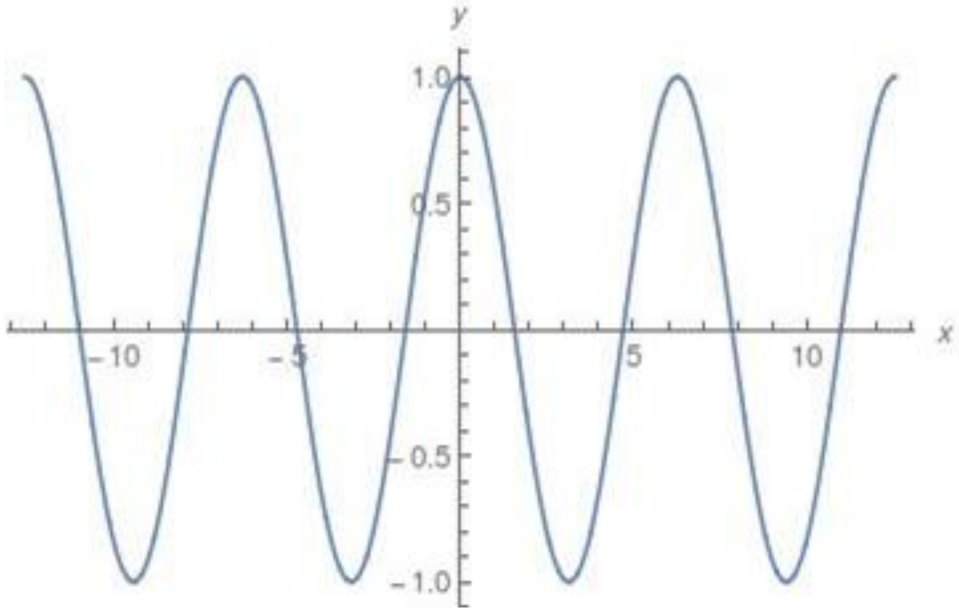
$\theta = \theta max \cos(2\pi f t)$ $f=1/T$ $2\pi f = \text{sqrt}(g/L)$

WAVES

$v = \lambda f = \lambda / T$
Intensity = Power/Area
Spherical Waves
$I = P/(4\pi r^2)$
Superposition and Interference of two sources
A=A1 + A2 constructive
A= |A1-A2| destructive



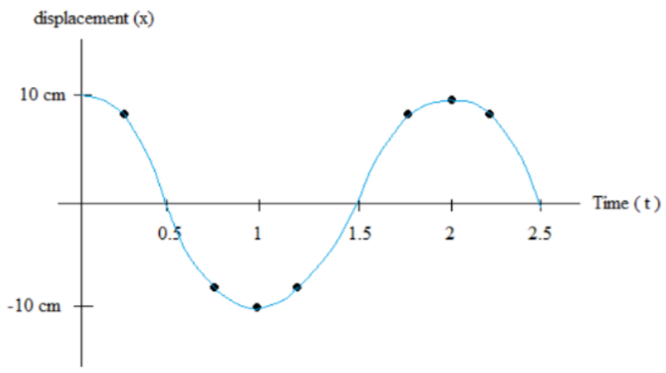




CLASSWORK ON WAVES

Q1) What is the wavelength of an earthquake that shakes you with a frequency of 13.0 Hz and gets to another city 50.0 km away in 15.0 s?

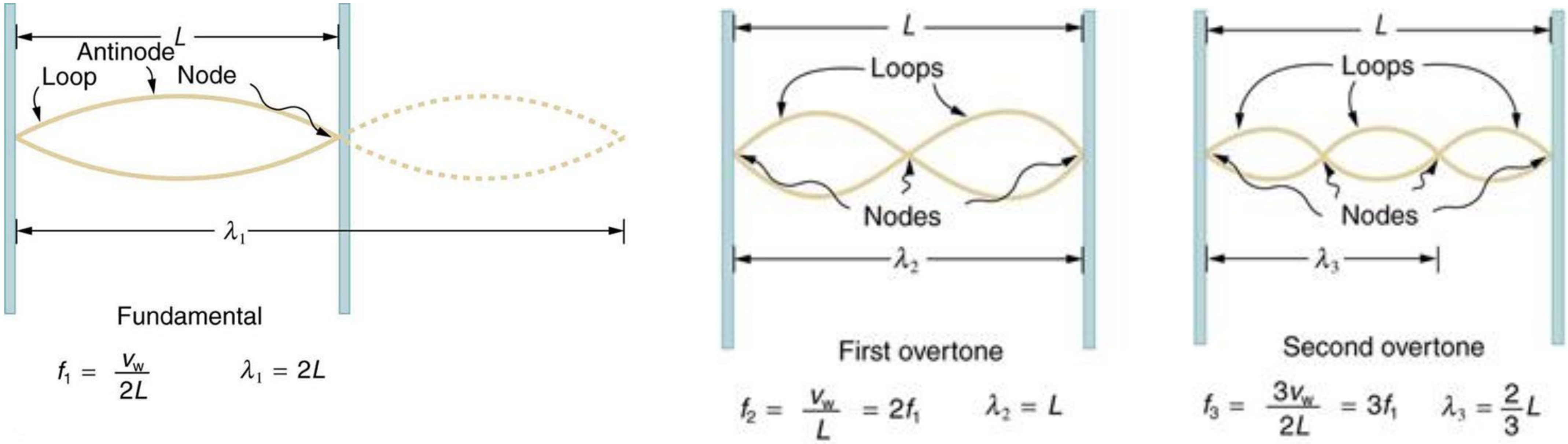
Q2) Using the graph, find the wavelength of the wave that has a velocity of 4.0m/s.



Q3)Radio waves transmitted through space at the speed of light ($3.0\ 10^8$ m/s) by the Voyager spacecraft have a wavelength of 0.120 m. What is their frequency?

Q4) Draw y vs x graph and y vs t graph of a wave with amplitude 2.0m, period 2.5 seconds and speed 4.0m/s
Q5) Two pulses with amplitude 0.2m and 0.3m interferes. Calculate the resultant amplitude if they are constructive or destructive

STANDING WAVES



For a standing wave, nodes are the points that does not oscillate
Antinodes are the maximums of the oscillation
Number of antinodes of a graph gives "n"
f = n Vw/(2L)   where Vw is the wave velocity f is the frequency and L is the length
λ = 2L/n

CLASSWORK STANDING WAVES

Q1) For a standing wave on a 2 meters long string, the second overtone is $f_3=1500$ HZ. Find the third overtone f_4 and calculate its speed

Q2) Wave speed on a 0.25m long string is 460 m/s. Calculate the first three possible frequencies on that string

Q3) Draw a standing wave with 4 nodes on a 1.5 meters long string.

Q4) Find the wavelength for the fundamental frequency if $f_5=2125$ Hz and wave speed is 450 m/s.

ADVANCED CLASSWORK FOR STANDING WAVES

A string instrument has length "L", mass "m" and it is under a force of tension "Ft". String produces sound with frequency "fn" by forming standing waves with n number of antinodes. Complete the table below using the known quantities and the formula.

f Frequency Hz	Wavelength (m)	n	Force of Tension Ft	Length (m)	Mass (kg)	Mass Density m/L	Velocity
f4=?		4		0.50	0.004		400 m/s
f5=1000 Hz				0.80	0.005		
	0.25			0.75	0.006		420m/s
f6=?		6		0.60	0.003		

$v = \lambda f = \lambda / T$ $v^2 = Ft/(mu)$ $mu = m/L$ $\lambda = 2L/n$ $f = n v / 2L$

REFERENCES

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