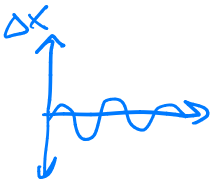
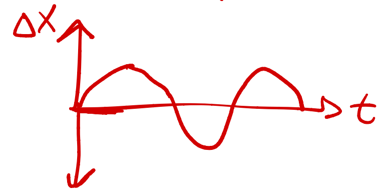
PHY 303K Final Study Session

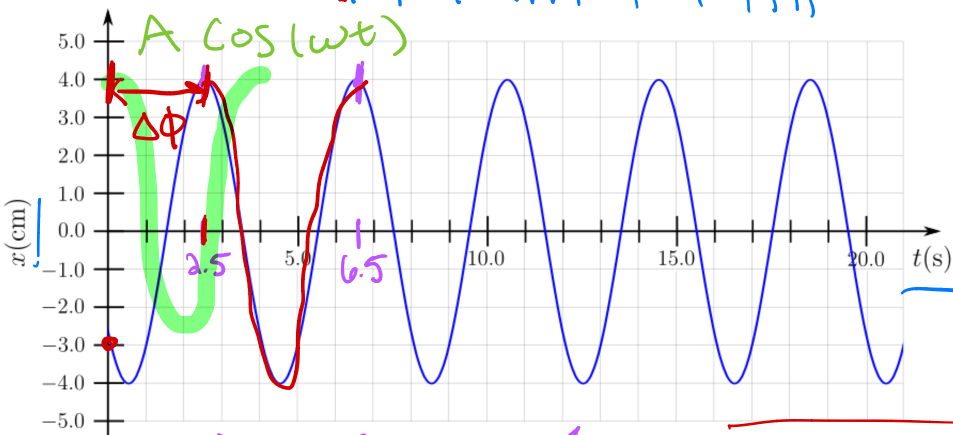
Relevant Concepts from HW 10:

- Reading plots of wave functions & dynamics
- Speed of sound in different mediums
- Doppler shift
- How to relate f, T, λ, etc.
- Oscillating pendulum

Problem 1: Some laboratory students are studying periodic motion using an oscillating mass on a spring. After recording data, they made the position *versus* time graph shown.







$\lambda = 6.5 - 2.5 = 4$

$\sin(\omega t - \frac{\pi}{2})$
$= \cos(\omega t)$

The function that represents the data on the graph may be written as

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

$$x = A\cos(\omega t + \phi) \quad \text{with} \quad \phi \in [0, 2\pi)$$

$f\lambda = \frac{\omega}{k}$, $\omega = 2\pi f$

$T = \frac{1}{f} \rightarrow f = \frac{1}{4s} \rightarrow \omega = \frac{\pi}{2}$

The phase constant for the graph presented is most nearly
MultipleChoice :

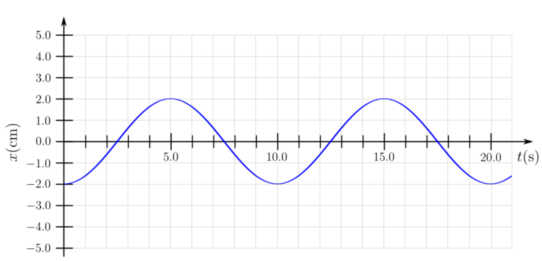
$x(t=0) = (4cm)\cos(\frac{\pi}{2}t + \phi)$

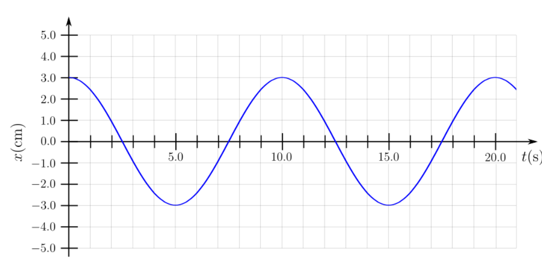
$-3 = 4\cos(\phi)$

$\cos\phi = \frac{-3}{4}$

1) $\phi = 135^\circ$
2) $\phi = 315^\circ$
3) $\phi = 270^\circ$
4) $\phi = 0^\circ$
5) $\phi = 180^\circ$
6) $\phi = 45^\circ$
7) $\phi = 225^\circ$
8) $\phi = 90^\circ$

Problem 2: Some Introductory Physics students are studying periodic motion using an oscillating mass on a spring. After acquiring data, they made position *versus* time graphs, including the two shown.

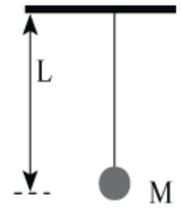




Select *all* attributes that are the same for both graphs. All phase constants are a multiple of 45°.
MultipleSelect :

1) amplitude
2) frequency
3) phase constant

Problem 6: A pendulum is shown in the figure to the right. It consists of a solid ball with uniform density and has a mass M and is suspended from the ceiling with a massless rod as shown in the figure. The ball on the pendulum is extremely small.



Randomized Variables

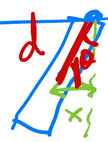
$L = 3.3$ m

Part (a) How does the period of the pendulum change if the mass is doubled? Choose the best answer.
MultipleChoice :

1) The period remains unchanged.
2) The period is increased by a factor of √2.
3) The period is decreased by a factor of √2.
4) The period is doubled.

Part (b) Find the period T of the pendulum for small displacements in s.
Numeric : A numeric value is expected and not an expression.
T = ____

Problem 7: A uniform rod of mass M and length L is free to swing back and forth by pivoting a distance x from its center. It undergoes harmonic oscillations by swinging back and forth under the influence of gravity.



$\cos\theta = \frac{x}{d}$

$d\cos\theta = x$

$\cos\theta \approx 1$

$d \approx x$

$I = I^{CM}_{rod} + Md^2$

$= \frac{1}{12}ML^2 + Mx^2$

Randomized Variables

$M = 2.2$ kg

$L = 1.4$ m

$x = 0.21$ m

$\omega = \sqrt{\frac{Mgx}{I}}$

$= \sqrt{gx/(\frac{1}{12}L^2 + x^2)}$

$\omega = \frac{2\pi}{T}$

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

$\hookrightarrow \omega = \sqrt{k/m}$

Part (a) In terms of M, L, and x, what is the rod's moment of inertia I about the pivot point.
Expression :
I = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, a, d, g, h, j, k, L, M, n, P, t, x

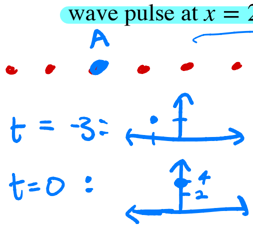
Part (b) Calculate the rod's period T in seconds for small oscillations about its pivot point.
Numeric : A numeric value is expected and not an expression.
T = ____

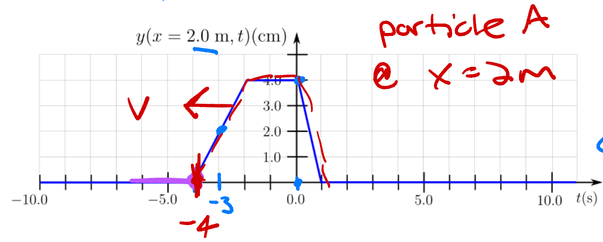
Part (c) In terms of L, find an expression for the distance x_m for which the period is a minimum.
Expression :
x_m = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, a, d, g, h, j, k, L, M, n, P, t, x

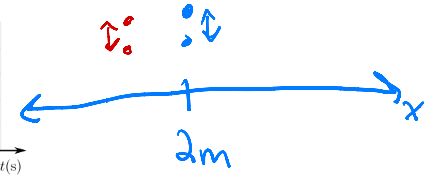
Part (c) What is the wavelength, in meters, of the wave?
Numeric : A numeric value is expected and not an expression.
λ = ____ m

Problem 10: Because the transverse displacements along a wave depend upon both position and time, there are two approaches to presenting its graph. If the position is held constant, then the transverse displacement *versus* time graph, a "history" plot, represents a single point along the wave acting as a simple harmonic oscillator. If the time is held constant, then the transverse displacement *versus* position graph, a "snapshot" plot, shows the appearance of the wave at an instant in time. The plot below is a history plot of a wave pulse at $x = 2.0$ m that is moving to the left at 1.0 m/s.



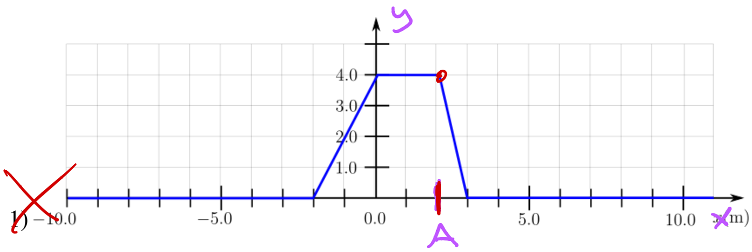


particle A @ x=2m



Which of these graphs is the corresponding snapshot plot at $t = -4.0$ s?
MultipleChoice :

$x = x_0 + vt$
$= 2 + t$

1)


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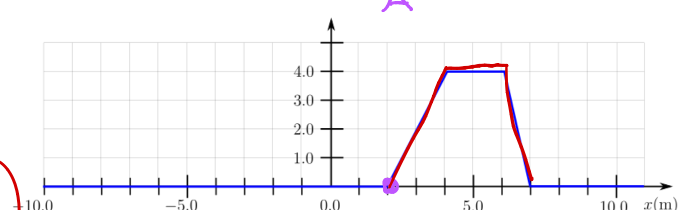
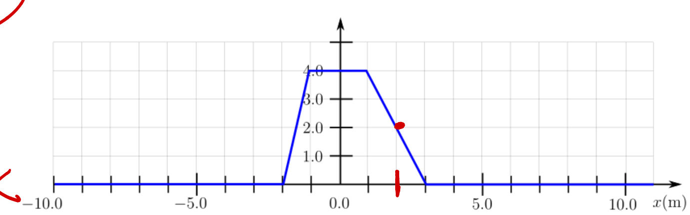
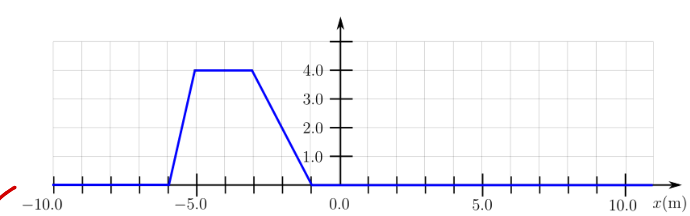
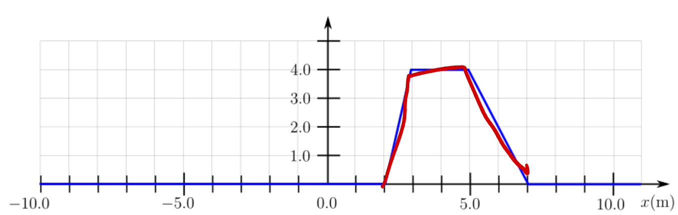


3)


4)


5)


Randomized Variables

$T = 32°$ C

$t = 1.9$ s

Part (a) Calculate the speed of sound in the valley in meters per second, assuming the speed at 0° C is 330 m/s.
Numeric : A numeric value is expected and not an expression.
v = ____

Part (b) How far are you from the canyon wall, in meters?
Numeric : A numeric value is expected and not an expression.
D = ____

Part (c) If you stood at the same point on a cold morning where the temperature was $T_2 = 4.5$ degrees C, how long would it have taken for you to hear the echo, in seconds?
Numeric : A numeric value is expected and not an expression.
t_2 = ____

Problem 16: The human ear can detect a minimum intensity of $I_o = 10^{-12}$ W/m^2, which has a sound intensity of 0 dB.

Randomized Variables

$\beta = 25$ dB

If the student hears a sound at *25* dB, what is the intensity of the sound?
Numeric : A numeric value is expected and not an expression.
I = ____

Problem 17: Ten cars in a circle at a boom box competition produce a *110*-dB sound intensity level at the center of the circle.

$I_{Tot} = N I_i$
(i = individual)

$$\beta_{tot} = 10 \log(I_{tot}/I_o)$$
$$= 10 \log(N I_i / I_o)$$
$$= 10 \log N + 10 \log(I_i/I_o)$$
$$= 10 \log N + \beta_i$$

I_2 / I_1	$\beta_2 - \beta_1$
2.0	3.0 dB
5.0	7.0 dB
10.0	10.0 dB

So $\beta_i = \beta_{tot} - 10 \log 10 = \beta_{tot} - 10 = 110 - 10 = 100$ dB

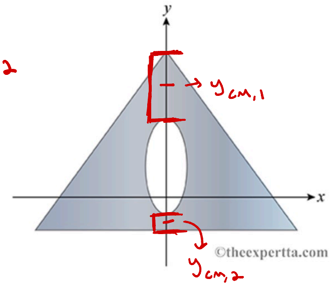
What is the average sound intensity level, in decibels, produced there by each stereo, assuming interference effects can be neglected?
Numeric : A numeric value is expected and not an expression.

Midterm 2

Problem 2 - c9.6.1 :

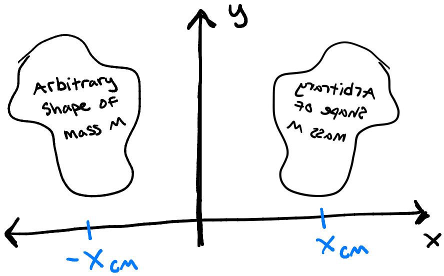
The figure illustrates a uniform metal sheet shaped like a triangle, with a hole cut in the center.

$$\Sigma y_{cm} = y_{cm,1} - y_{cm,2}$$



Part (a) **Where is the center of mass of this object, relative to the coordinate system shown?**

The triangle looks isosceles, with the y-axis as its axis of reflection symmetry. The hole too has reflection symmetry through the y-axis. Since the metal sheet is uniform, we deduce that the object shown in the figure has reflection symmetry through the y-axis. It then follows that the object's center of mass must lie on the y-axis. The only choice that is consistent with our conclusion is "Somewhere on the y-axis, where x = 0."



When object of uniform density reflected across y-axis,

$$\Sigma x_{cm} = x_{cm} - x_{cm}$$
$$= 0$$

Problem 11 - Classic Diver Problem v4 :

Full solution not currently available at this time.

Former UT Diver Alison Gibson, who we will assume has a mass of *50.6* kilograms, steps off a diving board and drops straight down into the water. The effect of the water is to contribute an average force of resistance of *1200* Newtons on the diver. If the diver comes to rest *4.1* meters below the water's surface, what is the total distance between the diving board and the diver's stopping point underwater?

Part (a) **If the diver comes to rest *4.1* meters below the water's surface, what is the total distance between the diving board and the diver's stopping point underwater?**

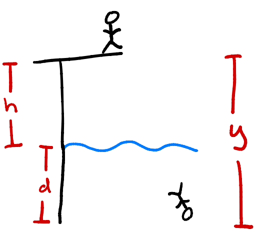
Total Distance = d*Fw/(9.81*m)
Total Distance = 4.1*1200/(9.81*50.6)
Total Distance = 9.912
Tolerance: ± 0.30

Seems to be just solving for h, not y

$$y = d + h$$

Can apply work since resistance from water

Can apply kinematic eqns since in free fall



@ $y = d$, $V_f^{air} = V_i^{water}$

So we want to solve one of our two eqns above for v^2 & plug it into the other to reduce our number of unknown variables.

For h; $\frac{1}{2} m v_f^2 = mgh$

For d; Work - Energy Theorem

$$W = |\Delta KE|$$
$$F \cdot d = |(KE)_f - (KE)_i|$$
$$= \frac{1}{2} m v_i^2$$

$$v^2 = \frac{2Fd}{m}$$

$$\frac{1}{2} m \left(\frac{2Fd}{m}\right) = mgh \qquad h = \frac{F \cdot d}{mg} \rightarrow y = d + \frac{Fd}{mg}$$

Midterm 3

Problem 3 - 9.2.16 :

One hazard of space travel is the debris left by previous missions. There are several thousand objects orbiting Earth that are large enough to be detected by radar, but there are far greater numbers of very small objects, such as flakes of paint.

Part (a) **Calculate the magnitude of the force, in newtons, exerted by a** 0.075 mg **chip of paint that strikes (and sticks to) a spacecraft window at a relative speed of** 3.75×10^3 m/s, **given the collision lasts** 5.75×10^{-8} s.

We can solve this problem by remembering that the impulse is equal to the change in momentum. We can find the change in momentum as we know the mass and initial velocity of the paint chip as well as knowing that the paint chip has no velocity after the collision. For the sake of getting a positive result for force (such that we don't have to change the sign to get the magnitude) let's allow the positive direction in this equation to be opposite the direction that the paint chip was initially traveling. As a consequence, the force exerted on the paint chip to stop it will be positive and the initial velocity of the paint chip will be negative in our equation.

$$I = \Delta p$$

$$I = F \cdot t \rightarrow F = \underline{I} / t = \frac{mV_i}{t}$$

$$I = p_f - p_i$$

$$I = \Delta P_{chip}$$

$$I = 0 - m(-v_i)$$

$$= P_f - P_i$$

$$Ft = mv_i$$

$$= 0 - (-mV_i)$$

$$F = \frac{mv_i}{t}$$

$$= mV_i$$

Now we can plug in values and solve for the force. As we do so, we must make sure to convert the mass from milligrams to kilograms.

$$F = \frac{0.075 \cdot 10^{-6}\ \text{kg} \ \cdot 3.75 \cdot 10^3\ \text{m/s}}{5.75 \cdot 10^{-8}\ \text{s}}$$

$$\boxed{F = 4891\ \text{N}}$$

Problem 4 - c11.1.4 :

A hollow sphere and a hollow cylinder of the same mass and radius are released at the top of an inclined plane. They are released simultaneously and from rest, and they roll down the incline without slipping.

Part (a) **Which is the first to reach the bottom of the incline?**

Both objects have the same mass, so both have the same potential energy at the top of the incline. At the bottom of the incline, all of the potential energy has been converted to kinetic, so both objects have the same kinetic energy at the bottom. However, due to different moments of inertia, the translational kinetic energy will be different.* The one with the greater translational speed will reach the bottom of the incline first.

The moment of inertia of a spherical shell and hollow cylinder can be found in a table. The are as follows:

First to bottom = Fastest Velocity

& Fastest V = Largest KE

$$I_{\text{sph}} = \frac{2}{3}MR^2$$
$$I_{\text{cyl}} = MR^2$$

We can set the kinetic energies of each at the bottom of the incline equal to each other, and see how they compare:

$$K_{\text{sph}} + K_{\text{R,sph}} = K_{\text{cyl}} + K_{\text{R, cyl}}$$

$\rightarrow (KE)_{Total} = (KE)_{Translational} + (KE)_{Rotational}$

$$\frac{1}{2}Mv_{\text{sph}}^2 + \frac{1}{2}I_{\text{sph}}\omega_{\text{sph}}^2 = \frac{1}{2}Mv_{\text{cyl}}^2 + \frac{1}{2}I_{\text{cyl}}\omega_{\text{cyl}}^2$$

$$\frac{1}{2}Mv_{\text{sph}}^2 + \frac{1}{2}\left(\frac{2}{3}MR^2\right)\omega_{\text{sph}}^2 = \frac{1}{2}Mv_{\text{cyl}}^2 + \frac{1}{2}(MR^2)\omega_{\text{cyl}}^2$$

$\omega = \frac{v}{r} \rightarrow r^2\omega^2 = v^2$

$$\cancel{M}\left(\frac{1}{2}v_{\text{sph}}^2 + \frac{1}{3}v_{\text{sph}}^2\right) = \cancel{M}\left(\frac{1}{2}v_{\text{cyl}}^2 + \frac{1}{2}v_{\text{cyl}}^2\right)$$

$$\frac{5}{6}v_{\text{sph}}^2 = v_{\text{cyl}}^2$$

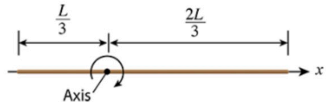
$$v_{\text{sph}} = \sqrt{\frac{6}{5}}v_{\text{cyl}}$$

Because at the bottom of the incline $v_{\text{sph}} > v_{\text{cyl}}$, the spherical shell will reach the bottom of the incline first.

$\boxed{\text{The spherical shell reaches the bottom first.}}$

Problem 5 - 10.5.12 :

The diagram shows a uniform rod of mass M and length L, where the axis of rotation is a distance of $\frac{L}{3}$ from one end.



Part (a) **Determine an expression for the moment of inertia of the rod.**

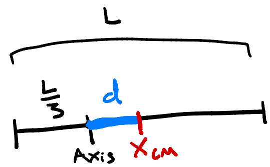
The moment of inertia can be determined two different ways.

Parallel Axis Theorem Method:

We will need the moment of inertia of a uniform rod with an axis of rotation about its center, which is $I_{CM} = \frac{1}{12}ML^2$. We will also need the distance, d, from the center of mass of the rod to the current axis of rotation. This distance is $\frac{L}{6}$.

Applying the parallel axis theorem:

$$\begin{aligned} I &= I_{CM} + Md^2 \\ &= \frac{1}{12}ML^2 + M\left(\frac{L}{6}\right)^2 \\ &= \frac{1}{12}ML^2 + \frac{1}{36}ML^2 \\ &= \frac{1}{9}ML^2 \end{aligned}$$



$$\begin{aligned} d &= X_{cm} - X_{axis} \\ &= \frac{L}{2} - \frac{L}{3} = \frac{L}{6} \end{aligned}$$

Problem 9 - 14.4.5 :

Using orbital data for satellites, you can find ratios of the masses of their parent bodies.

Parent	Satellite	Average orbital radius r(km)	Period T(y)	r^3/T^2 (km^3/y^2)
Earth	Moon	3.84×10^5	0.07481	1.01×10^{19}
Sun	Earth	1.496×10^8	1.000	3.35×10^{24}
	Jupiter	7.783×10^8	11.86	3.35×10^{24}
Jupiter	Io	4.22×10^5	0.00485 (1.77 d)	3.19×10^{21}
	Europa	6.71×10^5	0.00972 (3.55 d)	3.20×10^{21}
	Ganymede	1.07×10^6	0.0196 (7.16 d)	3.19×10^{21}
	Callisto	1.88×10^6	0.0457 (16.19 d)	3.20×10^{21}

Part (a) **Find the ratio of the mass of Jupiter to that of Earth based on only data in the table.**

Kepler's third law of plantary motion provides a relationship between the orbital radius and the orbital period of a satellite moon.

$$\frac{R^3}{T^2} = \frac{GM}{(4\pi^2)} = \text{Constant For given planet of mass } M$$

where M is the mass of the planet. Solving for the mass, we find

$$M_P = \frac{4\pi^2}{G}\left(\frac{R_P^3}{T^2}\right)$$

Using the satellite orbital data for each planet from the table, we can find the ratio of the masses.