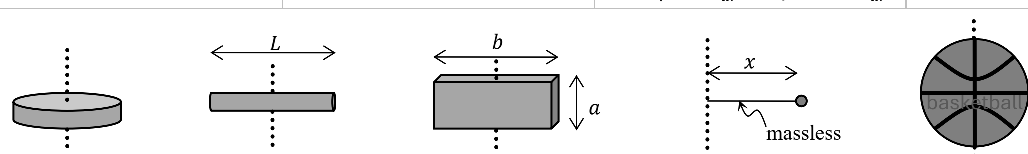
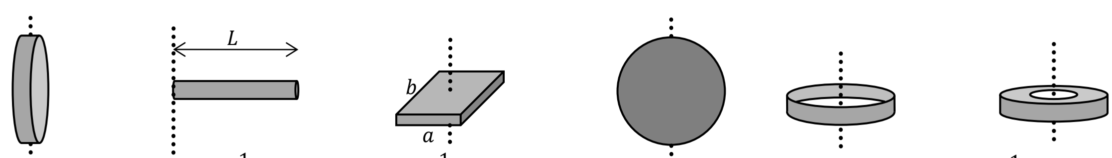
AFTER I GIVE THE SIGNAL TO BEGIN YOU CAN REMOVE THIS SHEET. DO NOT TURN IT IN!

162sp25t2c – Once the exam has officially started, remove the top sheet. The remaining sheets comprise your exam. It is each student's individual responsibility to ensure the instructor has received her or his completed exam. Any exams not received by the instructor earn zero points. Smart watches, phones, or other devices (except scientific calculators) are not permitted during the exam.

$1\ \text{kg}\cdot\frac{\text{m}}{\text{s}^2}=1\ \text{N}$	$1\ \text{N}\cdot\text{m}=1\ \text{J}$	$1\ \text{Pa}=1\frac{\text{N}}{\text{m}^2}$	$1\ \text{W}=1\ \frac{\text{J}}{\text{s}}$
$\Delta x=\frac{1}{2}a_xt^2+v_{ix}t$	$v_x=\frac{dx}{dt}$	$a_x=\frac{dv_x}{dt}$	$v_{max}=\omega_0x_{max}$
$\Sigma\vec{F}=m\vec{a}$	$\Sigma\vec{\tau}=I\vec{\alpha}$	$\mathcal{P}=\frac{dE}{dt}$	$a_{max}=\omega_0^2x_{max}$
$\omega=2\pi f=\frac{2\pi}{\mathbb{T}}$	$F_{spring}=k\lvert x\rvert$	$\omega_0=\sqrt{\frac{k}{m}}$	$x(t)=A\cos(\omega_0t+\phi)$
$-\omega_0^2x=\ddot{x}$	$-\frac{\kappa}{I}\theta=\ddot{\theta}$	$-\frac{g}{L}\theta=\ddot{\theta}$	$-\frac{mgr_{CM}}{I_{pivot}}\theta=\ddot{\theta}$
$K=\frac{1}{2}mv^2$	$U=\frac{1}{2}kx^2$	$\sin\theta\approx\tan\theta\approx\theta$	$I_{\parallel axis}=I_{\text{CM}}+md^2$
$\vec{F}_{drag}=-b\vec{v}$	$x(t)=Ae^{-bt/2m}\cos(\omega_dt+\phi)$	$\omega_d=\sqrt{\omega_0^2-\left(\frac{b}{2m}\right)^2}$	$\vec{\tau}=\vec{r}\times\vec{F}\to rF\sin\theta$ + R.H.R.
$\vec{F}_{driver}=F_0\sin(\omega_{dr}t)\,\hat{\imath}$	$x(t)=A\cos(\omega_{dr}t+\phi)$	$A=\frac{F_0}{\sqrt{m^2(\omega_{dr}^2-\omega_0^2)^2+b^2\omega_{dr}^2}}$	$x_{CM}=\frac{x_1m_1+x_2m_2}{m_1+m_2}$



$I_{disk}=\frac{1}{2}mR^2$ $I_{\substack{thin\\rod}}=\frac{1}{12}mL^2$ $I_{\substack{thin\\plate}}=\frac{1}{12}mb^2$ $I_{\substack{pnt\\mass}}=mx^2$ $I_{\substack{spherical\\shell}}=\frac{2}{3}mR^2$

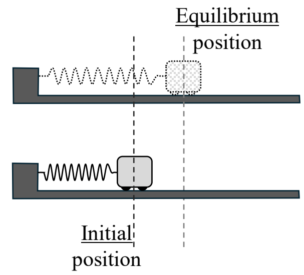


$I_{disk}=\frac{1}{4}mR^2$ $I_{\substack{thin\\rod}}=\frac{1}{3}mL^2$ $I_{\substack{thin\\plate}}=\frac{1}{12}m(b^2+a^2)$ $I_{\substack{solid\\sphere}}=\frac{2}{5}mR^2$ $I_{\substack{thin\\ring}}=mR^2$ $I_{\substack{thick\\ring}}=\frac{1}{2}m(R_i^2+R_o^2)$

$y(x,t)=y(x\pm vt)$	$y(x,t)=A\sin(kx-\omega t+\phi)$	$k=\frac{2\pi}{\lambda}$	$v=f\lambda=\frac{\lambda}{\mathbb{T}}=\frac{\omega}{k}$
$\mu=\frac{m}{L}$	$v=\sqrt{\frac{F_{Tension}}{\mu}}$	$\mathcal{P}_{avg}=\frac{1}{2}\mu v\omega^2A^2$	$\frac{\partial^2y}{\partial x^2}=\frac{1}{v^2}\cdot\frac{\partial^2y}{\partial t^2}$
$y_{total}(x,t)=y_1(x,t)+y_2(x,t)+\cdots$	$s(x,t)=s_{max}\,\mathbf{cos}(kx-\omega t)$	$\Delta P(x,t)=\Delta P_{max}\,\mathbf{sin}(kx-\omega t)$	$\Delta P_{max}=v_{sound}\rho\omega s_{max}$
$v_{sound}=\sqrt{\frac{Bulk\ Modulus}{density}}$	$v_{\substack{sound\\air}}\approx331.4\frac{\text{m}}{\text{s}}+\left(0.61\frac{\text{m}}{\text{s}\cdot°\text{C}}\right)T_C$	$I=\frac{\mathcal{P}ower}{Area}$	$I=\frac{1}{2}\rho v\omega^2s_{max}^2$
$\beta=10\ \text{dB}\ \log_{10}\frac{I}{I_0}$	$I_0=10^{-12}\frac{\text{W}}{\text{m}^2}$	$\Delta r\approx d\sin\theta$ if $d\ll L$	$f_{beat}=\lvert f_1-f_2\rvert$
$\Delta r=\lvert r_1-r_2\rvert$	$\phi=\frac{\Delta r}{\lambda}360°$	$\Delta r_{des}=(odd\ integer)\frac{\lambda}{2}$	$\Delta r_{con}=(even\ integer)\frac{\lambda}{2}$
$f'=f_{source}\left(\frac{c\pm v_o}{c\mp v_s}\right)$	Use $+v_o$ if obs. towards source. Use $-v_s$ if source towards obs.	Mach # $=\frac{v_{source}}{v_{sound}}=\frac{1}{\sin\theta_{Mach}}$	$\sin(90°-\theta)=\cos\theta$

$\text{T}=10^{12}$	$\text{G}=10^9$	$\text{M}=10^6$	$\text{k}=10^3$	$\text{c}=10^{-2}$	$\text{m}=10^{-3}$	$\mu=10^{-6}$	$\text{n}=10^{-9}$	$\text{p}=10^{-12}$	$\text{f}=10^{-15}$	$\text{a}=10^{-18}$

Name:____

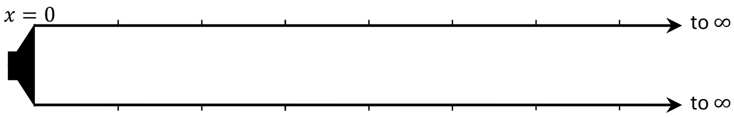


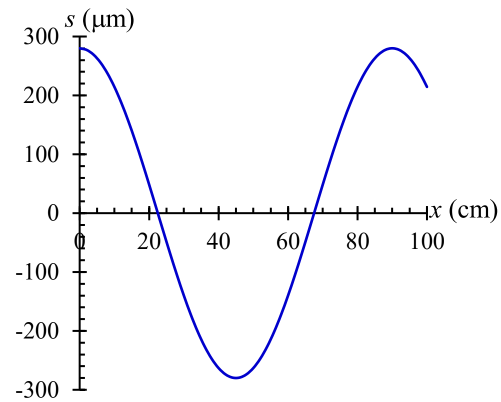
A 424-gram mass slides with negligible friction across a horizontal level surface.
The mass is connected to the wall by a spring of negligible mass.
The mass is initially 235 mm to the left of the equilibrium position (time $t = 0$).
The mass is initially moving to the right with speed $2.00 \frac{\text{m}}{\text{s}}$.
The period of oscillations is 1.700 s.

Intermediate rounding errors will cost you points!

1a) Determine angular frequency.
1b) Determine the spring constant.
**1c) Determine the phase angle assuming $x(t) = x_{max}\cos(\omega_0 t + \phi)$.
1d) Determine the amplitude of oscillation.
**1e) Determine position of the mass at $t = 1.00$ s (relative to the equilibrium position).

1a	
1b	
1c	
1d	
1e	





A sound wave propagates down an infinitely long pipe filled with air.
The density of air inside the tube is $1.215 \times 10^{-3}\,\frac{\text{g}}{\text{cm}^3}$.
A plot of displacement versus position (for time $t = 0$) is shown.
The speed of sound in the tube is $348.1\,\frac{\text{m}}{\text{s}}$.
**2a) Determine wavenumber (physics definition, not chemistry's).
**2b) Determine period.
**2c) Determine the air temperature.
2d) Determine maximum overpressure in the tube.

2a	
2b	
2c	
2d	

3) On a day when the speed of sound is $343\,\frac{\text{m}}{\text{s}}$, a supersonic plane has Mach angle $30.0°$. If the plane slows down, what happens to the Mach angle? Circle the best answer.

Remains constant	Increases	Decreases	Impossible to determine without more info

4a) A *damped* oscillator is governed by the differential equation

$$-kx - b\dot{x} = m\ddot{x}$$

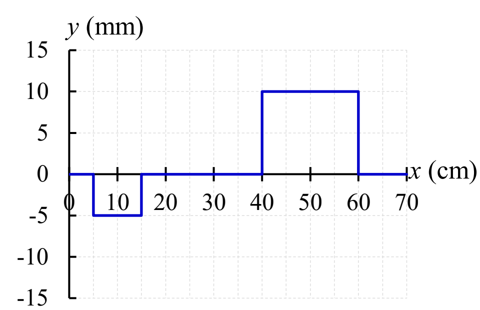
The mass is pulled some distance from equilibrium and released from rest at time $t = 0$. The damping constant b is *extremely* small. Which of the following best describes position of the oscillator as a function of time? Circle the best answer.

$x(t)$ exponentially *decays* as it returns to the equilibrium position	$x(t)$ oscillates with constant amplitude *smaller* than undamped oscillations	$x(t)$ oscillates with gradually *increasing* amplitude	Impossible to determine without more information
$x(t)$ exponentially *grows* as it returns to the equilibrium position	$x(t)$ oscillates with constant amplitude *larger* than undamped oscillations	$x(t)$ oscillates with gradually *decreasing* amplitude	

4b) A horizontal mass-spring system is used to create a *damped*, *driven* oscillator with resonant frequency 999 Hz. This oscillator is driven at frequency 444 Hz. Which of the following should *decrease* the oscillation amplitude? Circle the best answer *or answers*.

Slightly decrease the spring constant	Slightly decrease the mass	Slightly decrease driving frequency	None of the other actions *increase* oscillation amplitude

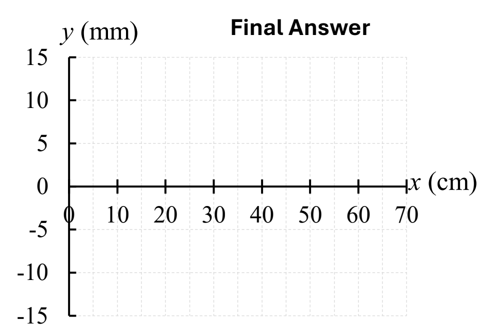
Two transverse wave pulses on a string both travel to the right at $10\,\frac{\text{cm}}{\text{s}}$. The right end of the string (at $x = 70$ cm) is fixed to a rigid support. Assume the figure at right shows the shape of the string at time $t = 0$.

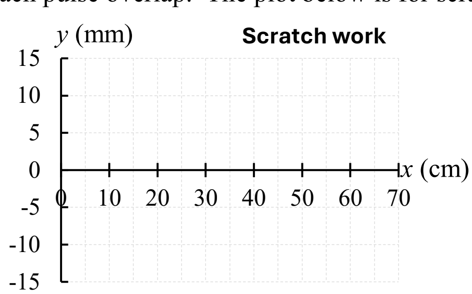


5a) At what time will the centers of each pulse be at the same position?

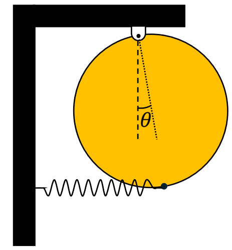
5a	

5b) Use the blank plot at right to sketch the shape of the string when the centers of each pulse overlap. The plot below is for scratch work.





A solid sphere (mass m & radius R) is connected to the ceiling with a frictionless pivot.
The bottom of the sphere is connected to the wall using a light spring (constant k).
The sphere is pulled to a small angle θ and released from rest.
Assume the spring force acts horizontally during small angle oscillations.
Air resistance is negligible.
******6) Determine *angular frequency* of small angle oscillations. Assume $\theta < 10°$.
I may give partial credit for deriving the result if multiple correct steps of the process are shown.
If you incorrectly plug into a memorized formula, no partial credit is available.
Simplify your work such that no fractions appear in the denominator of your final result.



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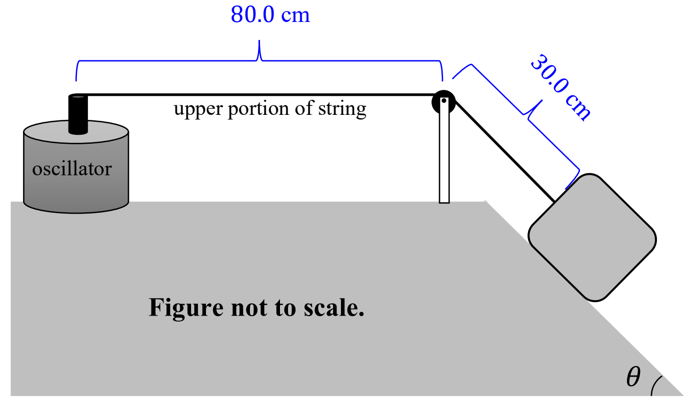
An oscillator is connected to a 1.000 kg mass on an inclined plane. Assume friction is negligible.
The inclined plane is designed such that the angle θ shown in the figure can be adjusted.

The string connecting the oscillator to the mass on the inclined plane has mass 9.25 g. When the oscillator operates at 76.4 Hz, the angle of incline is adjusted until a standing wave with four antinodes is observed on the upper portion of the string.

Do *not* assume the figure is drawn to scale!



******7) Determine the angle of the incline.
I must be able to easily follow your work if you want partial credit.

7	

A drone flies directly towards a stationary wall while emitting a tone at constant frequency.
The drone determines the echo from the wall is shifted by 8.50%.
The speed of sound in air on this particular day is c.

8a) Is the frequency of the echo shifted up or down? Circle the best answer.

No shift	Upwards	Downwards	Impossible to determine without more information

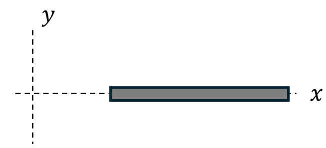
****8b) Determine the speed of the drone.
Answer as a number with 3 sig figs times c.

8b	

A cable with its left end 1.000 m from the origin has linear mass density given by

$$\mu(x) = kx^6$$

The cable is 2.00 m long and is under $120\underline{0}$ N of tension. Figure not to scale.
A student observes a wave-pulse traveling from the left end to the right end in 0.500 s.



9a) As the pulse traveled left to right, which of the following best describes wave speed?
Circle the best answer.

Wave speed was increasing	Wave speed was constant	Wave speed was increasing	Impossible to determine without more info

9b) Determine the units appropriate for the constant k.

****9c) Determine a numerical value of the constant k (include the units).

9b	
9c	

***Extra Credit:** Extra credit is worth almost nothing. Do this problem only after the rest of your test is complete and you've checked all your work, but you still have extra time. All work must be on this page & easy to follow.

Consider a horizontal mass spring system with negligible friction.
Suppose you know the initial position (x_i), initial velocity (v_i), and period $(\mathbb{T})$.
You do NOT know the mass or the spring constant.
Is it possible to determine the amplitude of oscillations with this information alone?
IF YES, derive an algebraic expression for the amplitude of oscillations in terms of the known parameters.
IF NO, clearly explain why not & state what additional parameter (or parameters) is required to determine amplitude.

Page intentionally left blank as scratch paper.
If you use this as scratch, you are still expected to put your correct answer in the box.
Furthermore, add a note to the problem telling me to “look for scratch”.

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If you use this as scratch, you are still expected to put your correct answer in the box.
Furthermore, add a note to the problem telling me to “look for scratch”.