↖ staple goes up there near the corner

Name (printed neatly) ________________________________

General Physics 121 - Exam 3 – December 4, 2018

Time started ______________ (record before you start – the honor code applies!)

Time ended ______________ (remember that honor code thing)

Place taken ______________

- To receive full credit for a problem, your work must convincingly demonstrate that you understand the physics involved behind the problem. That means not only providing the correct answer but showing how you obtained your answer.
- Questions represent a mix of conceptual and quantitative issues. Questions are scored according the rubric on the next page
- You may not consult the textbook, your notes, or any source of information other than the equations below.
- You may choose any continuous, uninterrupted 3-hour period in which to take this exam.
- You may use a calculator provided it is not programmed with course-specific information.
- It is important that your answers be neat and clear. Legible handwriting and clear exposition are required, not optional
- Use your own, lined paper. Nothing written on this exam will be graded. Do not use paper ripped from a spiral-bound notebook with jagged edges.
- Include raw algebraic equations and identify variables. Include units (m, s, m/s, etc.) in calculations and carry them through.
- When finished, place this entire exam atop your responses arranged in sequential order, straighten all the edges, and staple them together before handing them in.
- You must turn in the exam to Dr. Pontius unless other arrangements have been made.
- **Use only one side of each page of paper.**
- **Do not write your name on any of the pages other than this cover sheet.**
- **Start each answer on a new sheet of paper.**
- **I reserve the right to assign additional penalties for violating these instructions.**

Signing the honor code also affirms that you are taking the exam during a time period that does not conflict with any other academic obligations.

Sign to indicate that you abide by the BSC Honor Code:

Don't panic

Reminder: Show all your work. Explain thoroughly and justify everything.

Level of demonstrated understanding	Example	Score
Complete	Correct reasoning and answer	10
	Correct reasoning; minor computational mistakes or omissions; reasonable answer	9
Partial	Some physics errors or a correct setup but no or incomplete execution; substantial omissions.	7
	Major physics errors or partial justification provided even if answer is correct; major omissions.	5
Little to none	Little of relevance or no justification provided even if answer is correct	3
	Very little of relevance	1
	Blank or just a restatement of the question	0

$$\Delta\vec{r} = \frac{1}{2}\vec{a}(\Delta t)^2 + \vec{v}_i\, t \qquad \Delta\vec{v} = \vec{a}\,\Delta t \qquad v_{xf}^2 = v_{xi}^2 + 2\,a_x\,\Delta x \qquad \sum_i \vec{F}_i = m\,\vec{a}_{com}$$

$$f_{s,\,max} = \mu_s N \qquad f_k = \mu_k N \qquad \Delta K_{friction} = f_k\, d \qquad W = \vec{F}\cdot\vec{d} \qquad P \equiv \frac{dW}{dt} = \vec{F}\cdot\vec{v}$$

$$\vec{F}_{12} = -\vec{F}_{12} \qquad \vec{P} \equiv m\,\vec{v} \qquad \vec{\tau} \equiv \vec{r}\times\vec{F} \qquad \sum_i \vec{\tau}_i = I\,\vec{\alpha} \qquad \vec{L} \equiv I\,\vec{\omega} \qquad \vec{L} = \vec{r}\times\vec{P}$$

$$\Delta\vec{P}_{total} = 0 \qquad \Delta U_g = mg\Delta h \qquad K_t = \frac{1}{2}mv^2 \qquad U_s = \frac{1}{2}k\,x^2 \qquad K_R = \frac{1}{2}I\,\omega^2$$

$$\Delta\vec{L}_{total} = 0 \qquad \theta = \frac{s}{r} \qquad \omega = \frac{v_t}{r} \qquad \alpha = \frac{a}{r} \qquad \omega \equiv \frac{d\theta}{dt} \qquad \alpha \equiv \frac{d\omega}{dt} \qquad a_r = \frac{v_t^2}{r}$$

$$\vec{r}_{com} \equiv \frac{\sum m_i\,\vec{r}_i}{\sum m_i} \qquad F_g = G\frac{mM}{r^2} \qquad \Delta U_g = -mMG\left(\frac{1}{r_f} - \frac{1}{r_i}\right) \qquad I_{A\,\&\,B} = I_A + I_B$$

$$x = A\cos(\omega t + \phi) \qquad v = -\omega A\sin(\omega t + \phi) \qquad a = -\omega^2 A\cos(\omega t + \phi)$$

$$y = A\sin(kx - \omega t) \qquad v = -\omega A\cos(kx - \omega t) \qquad a = -\omega^2 A\sin(kx - \omega t)$$

$$F = -k\,\Delta x \qquad T = \frac{1}{f} = \frac{2\pi}{\omega} \qquad k = \frac{2\pi}{\lambda} \qquad v = \lambda f \qquad v = \sqrt{\frac{T}{\mu}}$$

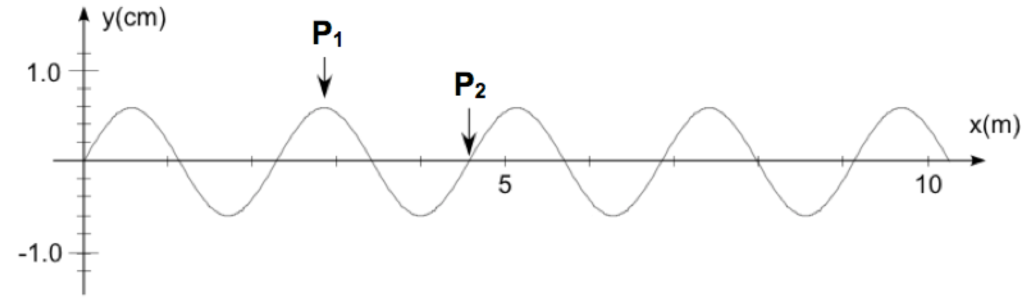
$$P = \frac{F}{A} \qquad \Delta P = \rho g\Delta h \qquad \omega = \sqrt{\frac{k}{m}} \qquad \omega = \sqrt{\frac{g}{L}} \qquad E = mc^2$$

1. A long taut string carries a sinusoidal wave traveling to the right at 42 m/s.

a. Find the frequency and wavelength of this wave, illustrated below at one instant.

b. Calculate the velocity and acceleration (including directions) of the string at positions $\mathbf{P}_1$ and $\mathbf{P}_2$ at the instant shown in the illustration below. Explain your reasoning.

c. What if this were a standing wave on the same string, fixed at the two ends shown, and shown at some unspecified instant? Find the velocities at $\mathbf{P}_1$ & $\mathbf{P}_2$ or explain why you can't.



2. The interior surface of a smooth bowl is curved like a section of a sphere with radius R = 44 cm. A cross-sectional view through the center is shown below. A small bead of mass m = 0.75 gram is released from rest at the position indicated, which is at an angle θ = 30° away from the center. The bead slides without rolling down the frictionless inside surface.

a) Draw free-body diagrams for the bead at its starting point and at the bottom. Explain the directions and relative magnitudes of the forces. Describe and characterize the motion.

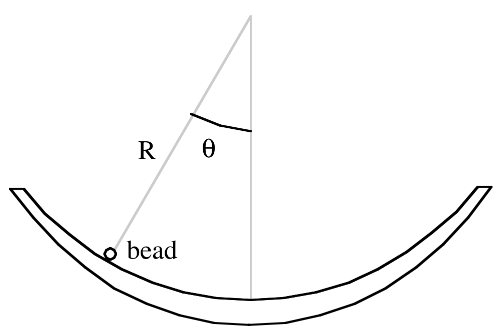
b) Find the work (including sign) done on the bead by the bowl from θ = 30° to the bottom.

c) Find the work (including sign) done on the bead by gravity between the same points.

d) Find the speed of the bead at the very bottom of the bowl.

e) Find the time required for the bead to reach the center.

Explain your reasoning and justify your approach for each answer.



3. Consider a mass attached to a spring oscillating back and forth in simple harmonic motion on a frictionless surface. In the following, be sure to define any technical terms you use and justify any equations you use:

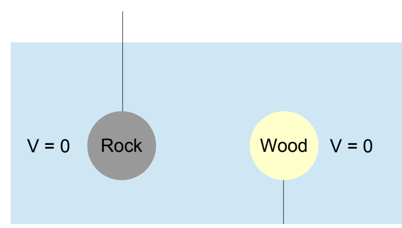
a. Describe in words the motion of the mass, specifying the variation of velocity and acceleration as functions of displacement and time, and relate them to one another throughout an entire cycle of motion.

b. Describe in words the variations of the force and energies, and relate them to one another throughout an entire cycle of motion.

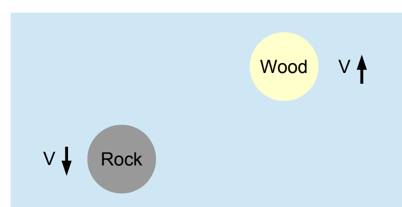
c. Explain why the physical parameters must appear in the equation where they do by arguing how changing each would affect the motion.

4. Two spheres of identical volume are completely immersed under water. The first is made of rock and hangs suspended from above a string. The second is made of lightweight wood and is tethered from below by a string. Explain your reasoning for the following questions.

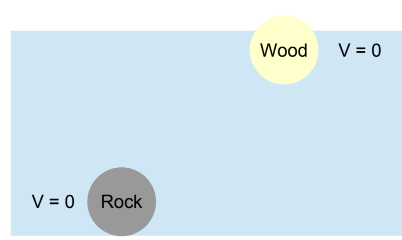
a. Identify all the forces on each of the two spheres in this state. Compare their directions and relative magnitudes, both on the same sphere and compared to the values on the other sphere.



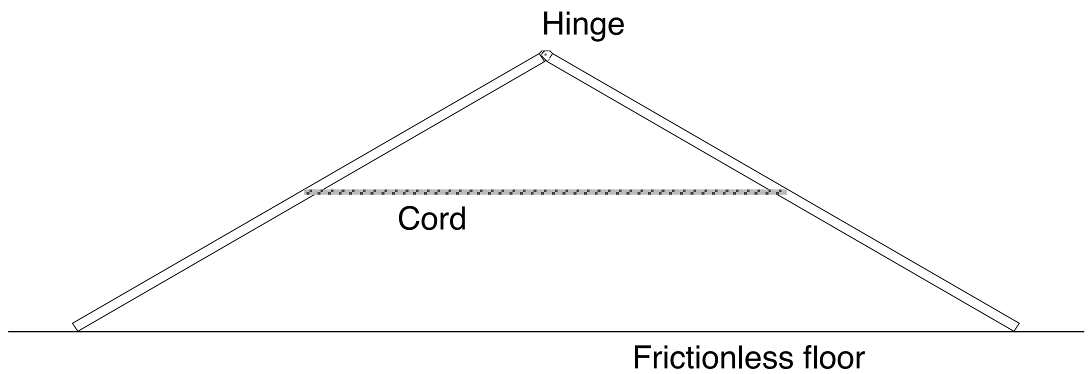
b. The two strings are now cut, so the rock sphere descends and the wood sphere rises. While still moving and before reaching the surface or the bottom, answer the same question. Have any forces changed?



c. Finally, the rock sphere rests on the bottom, and the wood sphere floats on the surface. Both are motionless. Compare the forces one last time and explain why.



5. Two identical, uniform planks, each of mass $m = 5.25$ kilograms and length $L = 3.50$ meters, are joined together at a hinge as shown below. A cord of length $\ell = 2.00$ meters stretches between their centers as they rest on a frictionless surface. Explain your reasoning for the following. Find the tension in the cord and the force at the hinge. Tip: Set up a separate FBD for each plank



6. Both Earth and Saturn orbit the Sun, but Saturn's orbit is 10 times larger in radius.
   a. If the Earth orbits at 30 km/s (which it does), find the orbital speed of Saturn.
   b. Find the length of Saturn's year, i.e., the amount of time it takes to complete one orbit around the Sun. Express your answer in Earth years.

   As always, thoroughly explain and justify your calculations. You might be interested to know that these are consequences of Kepler's laws for planets with circular orbits. The full version applies for elliptical orbits, but for most planets in our solar system, this is an excellent approximation.