⇖ staple goes up there near the corner

Name (printed neatly) ________________________________

General Physics 121 - Exam 3 – December 2, 2014

Time started ______________

Time ended ______________

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 only one side of each page of paper.
- Box your final answers to help me locate and identify them quickly
- 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.
- Do not write your name on any of the pages other than this cover sheet.
- Start each answer on a new sheet of paper.
- 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.
- **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.

Honor code:

Don't Panic!

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

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

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

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

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

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

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

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

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

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

Grading rubric:

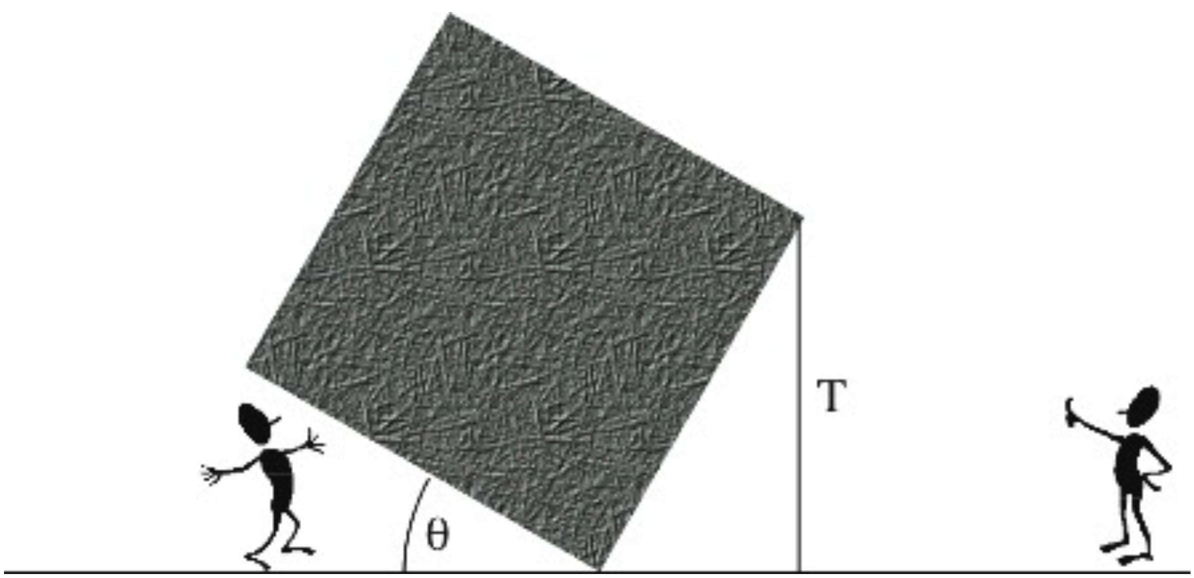
Level of demonstrated understanding	Example	Score
Complete	Correct, fully justified reasoning and answer	10
	Correct reasoning; minor computational mistakes or omissions; reasonable answer	9
Partial	Some physics errors or a correct setup but no or incomplete execution; substantial omissions.	7
	Major 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

Data that may or may not be of value to you:

$q_{electron} = 1.60 \times 10^{-19}$ C	$R_{Earth} = 6370$ km
$k_e = 8.99 \times 10^{9}$ N×m²/C²	$G = 6.673 \times 10^{-11}$ N × m²/kg²
$m_o = 4\pi \times 10^{-7}$ T× m/A	$e_o = 8.85 \times 10^{-12}$ C²/N×m²
$mF = 10^{-6}$ F	$nT = 10^{-9}$ T
$n_{water} = 1.3333$	$n_{glass} = 1.500$
$m_{proton} = 1.67 \times 10^{-27}$ kg	$m_{electron} = 9.11 \times 10^{-31}$ kg

g = 9.80 N/kg	1 N = 0.225 lb	$c = 3.00 \times 10^{8}$ m/s
1 mile = 1619 m	1ft = 0.305 m	1 inch = 2.54 cm
1 ton = 10^3 kg	1 mile = 1.609 km	1 Btu = 252 cal

1. Consider the following remarkable work of art: A uniform 116-ton cube (recall that 1 ton = 10^3 kg), each side of length L = 3.5 meters, made of recycled Buffalo Rock Ginger Ale cans and carefully supported on its lower corner at an angle of θ = 31°. In addition, a single steel cable connects the right corner of this impressive work (not in the physics sense) to the ground directly below. The cable is perfectly vertical, absolutely inflexible, rather strong, and very expensive. Find the tension in the cable and the force exerted by the ground on the lower corner of the cube. Express your answers in kN. Explain your reasoning.



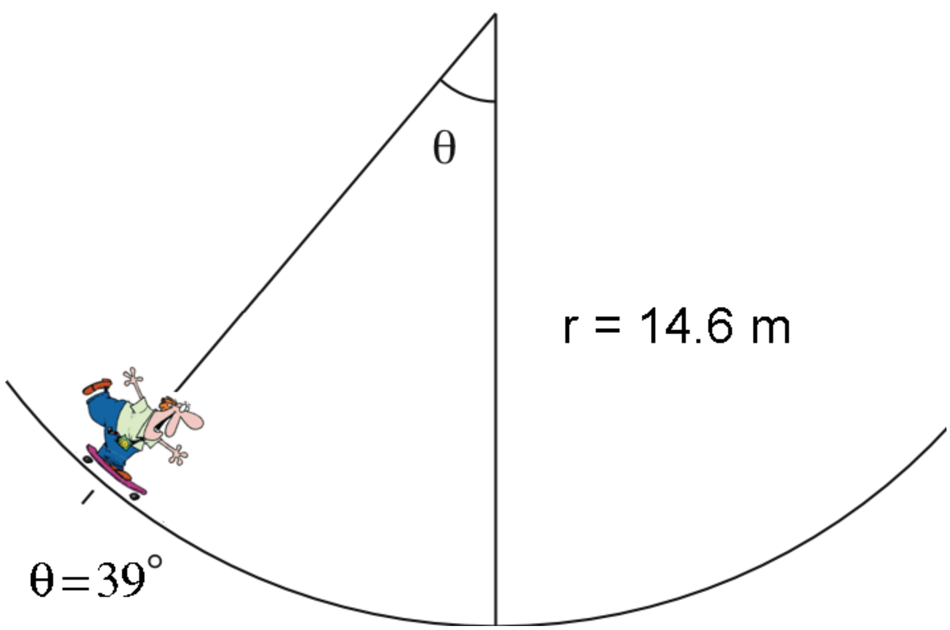
2. A body of mass m_o atop a frictionless surface is attached to an ideal horizontal spring and allowed to move back and forth with amplitude A. Answer the following thoroughly and justify your answers with coherent, verbal explanations. If you write out any equations, you must still interpret them in meaningful sentences.

a. Describe the motion of the body, and explain how speed v and acceleration a vary as the displacement changes. Specify the positions where each obtains its maximum and minimum magnitudes.

b. In that same situation, consider the instant when the displacement is at half the amplitude. Calculate the ratio of the speed and acceleration relative to their maximum values.

c. If the mass of the body is now halved while the amplitude remains the same, how do the maximum speed and acceleration compare to their original values? As always, explain!

3. Daring Dave deigns to display death-defying derring-do during Denver's decidedly decadent daily demonstrations of dreadlock-discouraging deeds. Dave adopts a stationary stance in inimitable style atop his DragonWheel5000™ Limited Skateboard with frictionless hyperlubricated wheels. At the instant shown, he is motionless. Draw a free-body diagram of Dave with his trusty board (treat them as a single object with combined mass of 85.2 kg) and calculate the net force acting upon him at this position (using appropriate coordinates that you establish. The long lines just indicate position, not a rope.). He then rolls toward the center, so repeat those questions for when he reaches the bottom of the circular track. How long does he take to get there from where he starts? You may ignore the moment of inertia of the wheels, but you must explain your reasoning thoroughly, which I should not have to tell you, but I do.



4. A pair of spheres having identical volumes V are tied to one another with a massless string. One sphere is composed of a uniform substance of density ρ_1 while the other is composed of a uniform substance of higher density ρ_2. When completely submerged below the surface in a fluid of density ρ_o, the pair is at rest in equilibrium with the denser sphere hanging directly below the lighter one.

a. Find the tension in the string in terms of the variables given and the gravitational field g.
b. Imagine now that you could choose another substance with a different ρ_1 for the lighter sphere, but keep ρ_o the same. Without changing the volumes (or g), what is the upper limit on possible values of ρ_2 that would still permit equilibrium? Explain why.

5. A long, taut string has a wave on it, and the displacement from equilibrium is described by the function $y(x, t) = 0.74\text{ cm} \times \exp[-(0.023\text{ m}^{-1} \cdot x + 4.4\text{ Hz} \cdot t)^4]$, where x is position along the string and t is time. Sometime later, the same string is observed to support a periodic disturbance with frequency 42 Hz. What is the wavelength of this new wave? Explain your reasoning as you go. ("exp(x)" is another notation for "e^x" when the exponent gets unwieldy.)

6. Gravity sucks, but just why does it suck? The answer can plainly be seen from Einstein's field equation for local space-time curvature:

$$R_{\alpha\beta} - \frac{1}{2} g_{\alpha\beta} R = \frac{8\pi G}{c^4} T_{\alpha\beta}$$

where $R_{\alpha\beta}$ is the Ricci curvature tensor, R is the scalar curvature, $g_{\alpha\beta}$ is the metric tensor, G is Newton's gravitational constant, c is the speed of light in a vacuum, and $T_{\alpha\beta}$ is the stress–energy tensor. (The cosmological constant Λ has been omitted for simplicity.) The Ricci tensor measures how much the intrinsic geometry of space-time as determined by the Riemannian metric tensor $R_{\alpha\beta\gamma\delta}$ differs from that of ordinary Euclidean space.

On second hand, ignore all that and answer the following. The altitude at which the International Space Station orbits is approximately 360 km, compared with the Earth's radius of 6370 km. The ISS completes one full orbit each 90 minutes, whereas so-called geosynchronous satellites are farther out and take exactly 24 hours to orbit. Unlike the ISS, they stay above the same position on the surface all the time. Find the radius of geosynchronous orbit. You must start from the equation list provided elsewhere on this exam, not by recalling a subsidiary equation from the text (though you may derive that equation and then use it. You may still omit the cosmological constant). And explain yourself!