↖ staple goes up there near the corner Name (printed neatly) ________________________________

# MODIFY #3

## General Physics 121 - Exam 2 – November 2, 2018

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!

$$x = \frac{1}{2} a_x (\Delta t)^2 + v_{ix} \Delta t + x_i \qquad v_x = a_x \Delta t + v_i \qquad v_{xf}^2 = v_{xi}^2 + 2 a_x \Delta x$$

$$\sum_i \vec{F}_i = m\vec{a} \qquad \vec{F}_{12} = -\vec{F}_{21} \qquad \vec{p} \equiv m\vec{v} \qquad \tau_i \equiv F_i d_i \qquad \tau_{net} = I\alpha$$

$$W = \vec{F} \cdot \Delta\vec{x} = F d \cos\theta \qquad F_{n,max} = \mu_s F_N \qquad F_k = \mu_k F_N \qquad \Delta K_{friction} = f_k d$$

$$\Delta\theta = \frac{\Delta s}{r} \qquad \omega = \frac{v_t}{r} \qquad \alpha = \frac{a_t}{r} \qquad \omega \equiv \frac{d\theta}{dt} \qquad \alpha \equiv \frac{d\omega}{dt} \qquad a_r = \frac{v_t^2}{r}$$

$$\Delta U_g = mg\Delta h \qquad K_T = \frac{1}{2} mv^2 \qquad U_e = \frac{1}{2} k (\Delta x)^2 \qquad K_R = \frac{1}{2} I \omega^2$$

$$\vec{F}_{ave} = \frac{\Delta\vec{p}}{\Delta t} \qquad \tau_{ave} = \frac{\Delta L}{\Delta t} \qquad \vec{F}_{com} = M\vec{a}_{com} \qquad I = \sum_i m_i r_i^2$$

$$F_s = -k \Delta x \qquad F_g = -m g \qquad P = \frac{\Delta W}{\Delta t} \qquad P = Fv \qquad \vec{\boldsymbol{\tau}} = \vec{\mathbf{r}} \times \vec{\mathbf{F}}$$

$$P = \tau \omega \qquad W = \tau \Delta\theta \qquad \vec{\mathbf{L}} = \vec{\mathbf{r}} \times \vec{\mathbf{P}} \qquad L = I\omega \qquad I_{A\,\&\,B} = I_A + I_B$$

$$\Delta\theta = \frac{1}{2} \alpha (\Delta t)^2 + \omega_i \Delta t \qquad \omega = \alpha \Delta t + \omega_i \qquad \omega_f^2 = \omega_i^2 + 2 \alpha \Delta\theta$$

$g = 9.80$ 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 metric ton = $10^3$ kg  
1 mile = 1.609 km  
1 Btu = 252 cal  
$a_g = 9.80$ m/s$^2$  
$G = 6.673 \times 10^{-11}$ N·m$^2$/kg$^2$  
$m_e = 9.11 \times 10^{-31}$ kg  
I, ring, axis through center = $MR^2$  
$m_p = 1.67 \times 10^{-27}$ kg  
I, solid disk, axis through center = 1/2 $MR^2$  
Surface area of cylinder = $\pi r^2 + 2\pi r H$  
I, solid ball, axis through center = 2/5 $MR^2$  
Volume of cylinder = $\pi r^2 H$  
I, thin rod, axis through center = 1/12 $ML^2$  
Area of circle = $\pi r^2$  
I, thin rod, axis through end = 1/3 $ML^2$  
1 Newton = 0.225 pounds  
1 meter = 3.281 ft

| Coefficients of friction | $\mu_s$ | $\mu_k$ |
|---|---|---|
| Copper against steel | 0.53 | 0.36 |
| Wood against rubber | 0.98 | 0.67 |
| Rubber against concrete | 0.95 | 0.80 |
| Teflon against teflon | 0.04 | 0.04 |

Grading rubric:

| 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 |

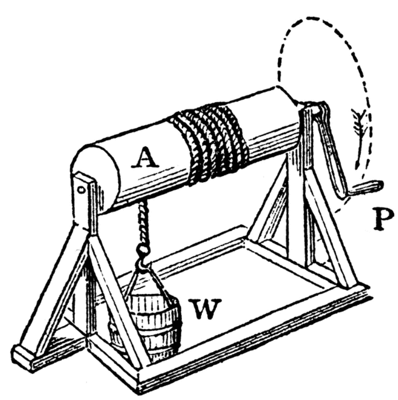
1. The figure below depicts one of the oldest known machines, typically found installed over wells. Discuss and explain the physics of this marvelous device and address these questions.

a) Compare (i) the force exerted at the crank *P* with (ii) the weight supported by the rope when the bucket rises at a constant rate.

b) Compare the (i) work expended by whoever turns the crank with (ii) the work done by gravity as it is used to raise a bucket of water during one revolution of the crank.

c) How would the answers to a and b change if the relative dimensions of the varied?

I want you to apply what you've learned from physics to reveal some insights into this somewhat familiar example of a simple machine. This is an essay question, so be thorough and eloquent.

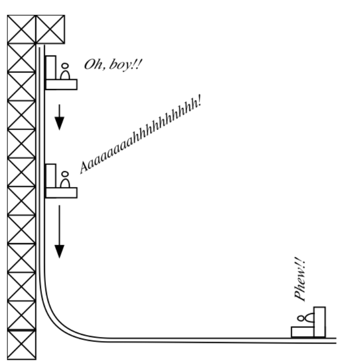



2. A conscientious motorist who always tries to drive the speed limit checks his speedometer by timing how long it takes to pass adjacent mile markers at 60 mph. Sure enough, it takes one

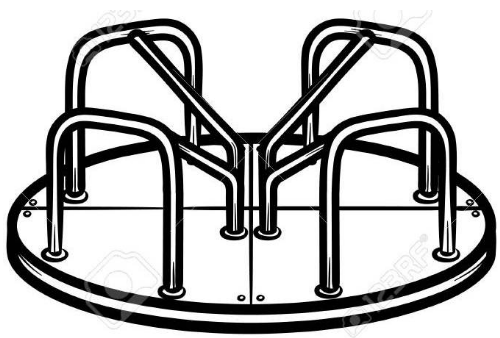
minute and the odometer advances exactly 1 mile. Soon thereafter, he replaces his old tires with new ones, and because the tread has not yet been worn down, these are 5% larger in radius. Given that the speedometer works by measuring the axle's rotational speed and using that to find the car's linear speed, is our motorist now more or less likely to find Officer Bubba's flashing lights in his rear view mirror? More precisely, if the speedometer indicates 65 mph, what is the car's actual speed? Explain your line of reasoning, don't simply state the result of your intuition.

3. A particular ride at 6 Flags Over Georgia takes a carriage full of passengers 45.3 meters above the ground. After a moment's pause—during which they all wait motionless, hold their breath, and question whether they should have had that second chili dog before getting into line—the carriage is suddenly released. It plunges down unrestrained toward the ground, guided by well-lubricated rails. Just before the bottom, the rails turn in a quarter circle and bring the cart into a horizontal path parallel to the ground (see the figure below, not to scale). During the final half of the horizontal part, brakes clamp on and the carriage comes to a halt over a distance of 57.2 meters. The total mass of carriage and passengers is 511 kilograms. Explain your reasoning throughout.

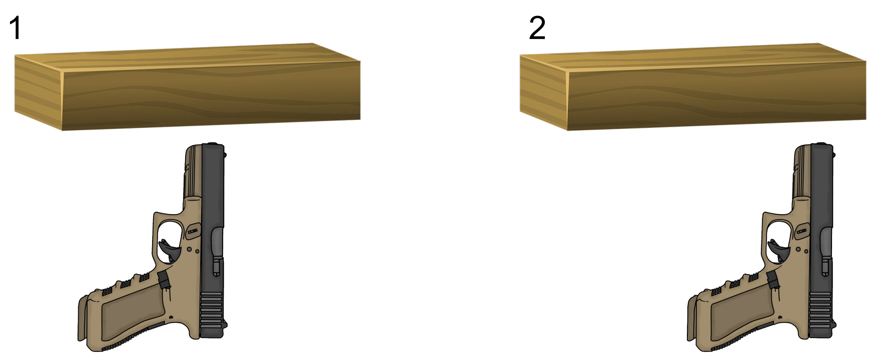
a) Find their speed in the horizontal section after the quarter-circle turn but before braking. Explain your approach and thoroughly justify any equations you use.
b) Find the force of friction exerted need to dissipate the kinetic energy via work.
c) In case the brakes didn't engage at all, there is a large spring at the very end of the horizontal section (not shown in the figure), which would have stopped the riders by compressing a distance of 4.3 meters. Find the spring constant.



4. Calvin is alone on his favorite merry-go-round (illustrated below, without Calvin on it) and holds fast to a bar at the outer edge as it rotates. This equipment is exceptionally well lubricated and would continue to turn indefinitely at the same speed if nothing changed. However, while it's still rotating Calvin pulls himself inward until he stands at its very center bracing himself against the bars. Explain how the angular velocity of Calvin and of the merry-go-round change when he moves inward and identify the relevant physical principles.



5. Two identical blocks of wood are placed at identical distances above the barrels of identical pistols loaded with identical bullets, as illustrated below. (The blocks are resting on supports that aren't shown.) The guns are both pointed upward, but the one on the left points through the center of block 1, while the one on the right points well off the center, near the end of block 2. After firing, both bullets will become fully embedded in the wood, so each block and bullet pair will move as a combined, rigid body. Describe and explain the subsequent motion of the blocks. Which block rises higher and why?

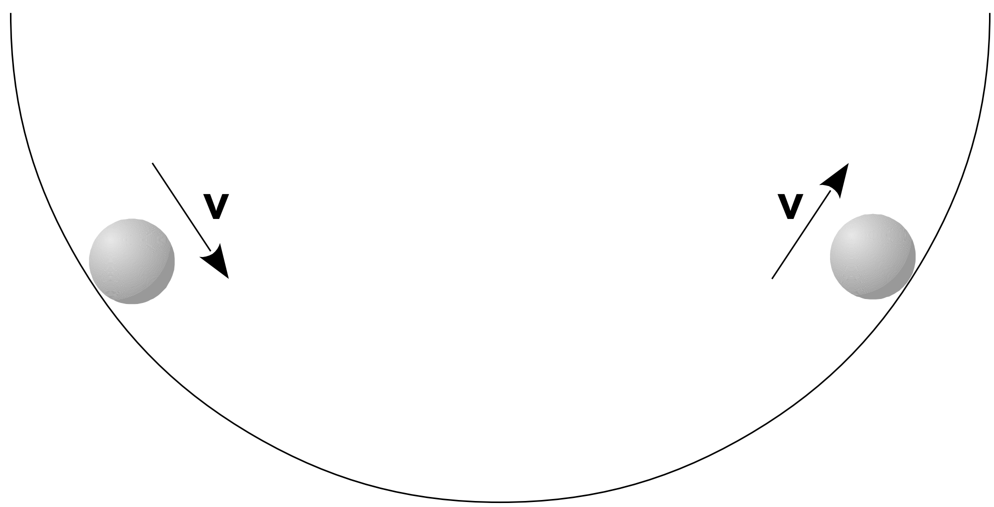


6. A hollow sphere of mass 35 grams and radius 1.13 cm is released from rest on the inside surface of a bowl of radius 12.95 cm. It rolls down the left side, then up the right. Consider the ball during two states

a) the ball is rolling down the left side and is 60° from the bottom

b) the ball is rolling up the right side and is 60° from the bottom

For each, draw the free-body diagram, then explain the physical cause of each force acting on the ball. Completely describe the motion of the ball, and explain how to determine the direction of each force. Finally, calculate the magnitude of each force.




Extra credit. Regarding the last question, is there an angle between 0° and 90° beyond which the ball would not roll if release from rest on the surface? Explain. You do not need to carry out a formal proof.