AP Exam 2: Momentum, Gravity, Rotation, and Waves

Your name-period here:

0 Preamble

You will have 45 minutes to complete the exam. This corresponds to roughly two minutes per multiple choice question (or part of a question) and 15 minutes for each short answer. All multiple choice questions are worth 1 point each, and each short answer is 4 points. Take a second and write your name. Students who forget this will need to provide me with a short story that includes their name and a castle in order to receive credit.

On the short answer questions, take the extra time to write legibly. I can't grade what I can't read!

1 Pick one (or more)!

1. A dowel with radius R_d is pushed through a hollow cylinder with outer radius R_c and inner radius r_d. The ends of the dowel are attached firmly so that the dowel is horizontal and cannot spin. Then a string is wrapped around the outside of the cylinder. Now a mass M_1 is attached to the end of the string. When M_1 is released, the cylinder will start to spin on the dowel, acting like a pulley. If the speed of the mass is measured to be v after it falls a distance Δh, what is the force of friction between the dowel and the inside of the cylinder? The cylinder has very low mass.

   A. $F_f = \frac{1}{2}mv^2 - m_1 g\Delta h$

   B. $F_f = r_c(\frac{1}{2}mv^2 - m_1 g\Delta h)$

   C. $F_f = \frac{R_c}{R_d \Delta h}(\frac{1}{2}mv^2 - m_1 g\Delta h)$

   D. $F_f = \frac{1}{\Delta h}(\frac{1}{2}mv^2 - m_1 g\Delta h)$

2. Two sine waves with the same frequency are traveling in opposite directions in the same medium. Based on this information alone, what can you conclude about the resulting wave?

   A. It will definitely be a standing wave.

   B. It will definitely be a traveling wave.

   C. It will definitely be a sine wave.

   D. None of the above.

3. A car and truck have the same momentum, but the car has twice as much kinetic energy as the truck. The objects stop in the same time, and the force on each car was constant with time. What can you conclude about the distance that each traveled before stopping?

   A. It was the same for both objects

   B. The car traveled further before stopping

   C. The truck traveled further before stopping

   D. We would need the mass ratio of the car and truck in order to answer this.

4. You roll two tires down a large hill. The black tire has a mass M and a coefficient of static friction with the hill of μ_s. The red tire has a mass of $2M$ and a coefficient of friction of $3\mu_s$ with the hill. Both roll without sliding, and the tires have their mass distributed identically. Which of these describes what will happen?

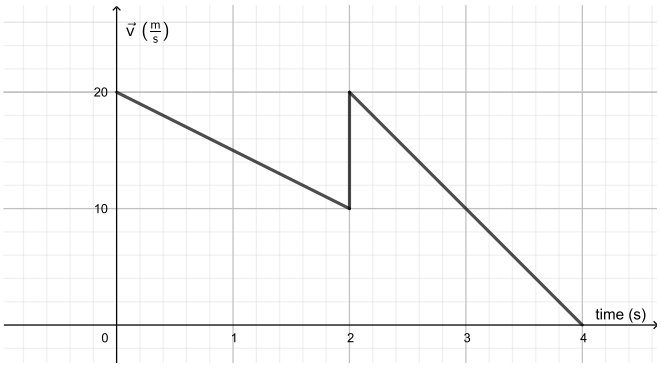
   A. The black and red tires will have the same speed when they reach the ground

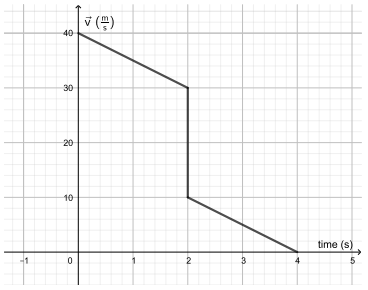
   B. The red tire will be traveling faster when it reaches the ground

   C. The black tire will be traveling faster when it reaches the ground

   D. The answer depends on the exact value of μ_s

5. You have the graphs of the velocity of two objects as a function of time as they slide across a frictionless table. Each has only the other object to collide with. The first object has mass M_1. M_1's graph is on the left.





(a) What was the mass of the second object, M_2?

A. $\frac{1}{2}M_1$

B. M_1

C. $2M_1$

D. $4M_1$

(b) What angle was the table placed at? You are on Earth where $g = 10\ \frac{\text{m}}{\text{s}^2}$.

A. $0°$ (aka horizontal)

B. $30°$

C. $60°$

D. $90°$ (aka vertical)

6. You (mass m) and a friend (mass $2m$) are standing on a block (mass $3m$) that rests on a frictionless surface. There is substantial friction between you and the block. You push your friend off the block. Your friend moves with a velocity $-v\hat{\text{x}}$. What will be your velocity?

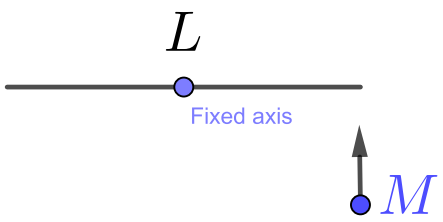
A. $+\frac{v}{2}\hat{\text{x}}$

B. $+v\hat{\text{x}}$

C. $+\sqrt{2}v\hat{\text{x}}$

D. $+2v\hat{\text{x}}$

7. For this problem, ignore gravity. There is a rod of length l and mass M that is free to rotate around an axis through its center. The rod is initially at rest along the x axis when it is impacted very near its end by a clay ball, also of mass M that is traveling with velocity $v\hat{y}$. What will be the final tangential speed of the mass once it sticks to the rod?



A. $\frac{4}{3}v$
B. $\frac{3}{4}v$
C. $\sqrt{\frac{4}{3}}v$
D. $\frac{2}{3}v$

2 I'm sure this is what you argue about in your spare time

1. Two students are arguing about the outcome of an experiment that they are about to perform with the rest of their class. The experiment will go like this:

   - Each student in the class will grab a tube with 1 of 4 predetermined lengths and a variety of different radii. No two tubes have both the same radius and the same length. The tubes are all much longer than their diameters. **The longest tubes are twice the length of the shortest.**
   - The teacher will walk down the line and put a vibrating tuning fork near one end of a tube.
   - Once it has been determined whether the tube resonated, the teacher will move to the next student in line and repeat until they reach the end.
   - The teacher has ensured that enough different tuning forks are available that every tube will be made to resonate at least once.

   The student's arguments are as follows:

   - Student A: Each tube can only support a single resonant frequency (the fundamental). Since the tubes are of different lengths, they will have different fundamental frequencies. Wider tubes will have much lower resonant frequencies than narrower ones. In 1-D, the waves will not lose energy due to geometric effects.
     Therefore: Each tube will have exactly one tuning fork that will cause it to resonate. and the energy of the resonance will continue to increase rapidly until the tuning fork is removed. For any other tube, no sound will result.
   - Student B: All tubes can support many different frequencies. The wider tubes will have basically no damping, while the thinner ones will have substantial damping. Tubes that are shorter can support lower frequencies.
     Therefore: A given tuning fork will cause all tubes of the same length to resonate. The shortest and longest tubes will never resonate together. When resonance is achieved, the thinner tubes will have very low amplitudes, but the wider tubes will have huge amplitudes.

   (a) Put a strike through any statement that either student made that was inaccurate. Circle or highlight any statement that a student made that was accurate.

   (b) Provide your own, correct, prediction for the outcome of the experiment. Explain your result using physics principles.

3 Leaving Earth means I can leave class, right?

You are selected for a space program and end up in a rocket moving away from Earth at a constant velocity. You want to determine how far you are from Earth using a pendulum that you have. The equation for the period of a pendulum is $2\pi\sqrt{\frac{l}{g}}$. You may assume that you don't travel far in the time it takes you to perform the experiment.

1. Show that the pendulum equation can be written in terms of the radius of Earth R, the distance from Earth Δr, the length, l and any fundamental constants that you need.
2. Show how the equation can be linearized to find the distance from the center of Earth.
    - x:
    - y:
    - slope:
3. Find the relative error between a measurement you make on the ISS and one made on the ground.