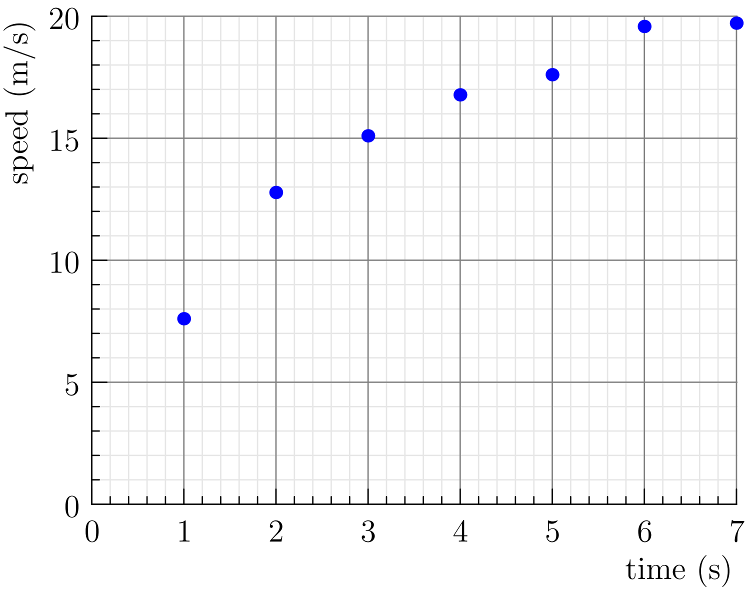
This is a test to determine whether you're familiar with the content of **Scholars High School Physics 1: Mechanics**.

To use this test, we recommend:

- Take the test. You may use a calculator, but don't get other outside help.
- Have someone else check your responses using the solutions on page 9 of this document. They should only tell you whether your answer was correct or not.
- Take a second try on any problems you got wrong the first time.

If by the second try you can solve at least ten of the problems, then significant portions of the course would be a review for you.

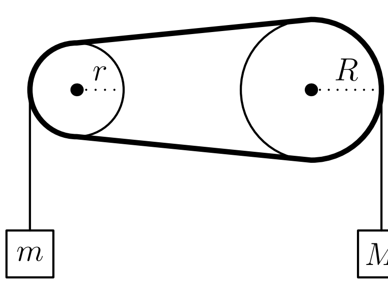
1. A tennis ball is dropped off a building. Its speed is recorded each second, and the results are shown below. After $7\ \mathrm{s}$ of falling, the tennis ball hits the ground. Estimate the height of the building. Your answer should be accurate to within $3\ \mathrm{m}$.



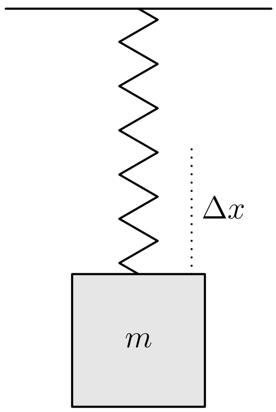
2. You take a video of a pendulum swinging, then analyze the video to determine the acceleration due to gravity. However, due to a software error, the video plays back in slow motion at half speed. If the true acceleration due to gravity is $10\ \mathrm{m/s^2}$, what acceleration due to gravity will you find (ignoring further experimental error) when you analyze the video?

3. Below is a system of two wheels, a belt, and two boxes hung from massless strings. The wheels have radii r and R and are connected by the belt, which cannot slip relative to the wheels. The wheels can rotate without friction but otherwise are not free to move. The boxes have masses m and M and are hung from the leftmost and rightmost points of the belt, respectively.

   Find an equation in terms of m, M, r and R so that this system is in equilibrium.

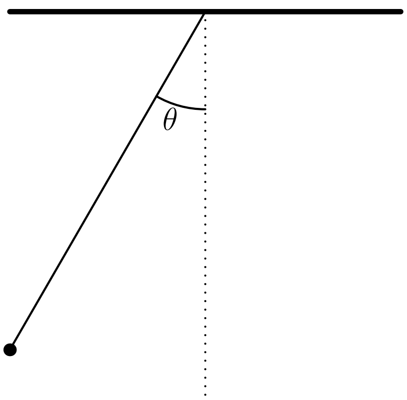


4. A mass m is hung vertically on a spring. At equilibrium, the spring stretches a distance Δx beyond its rest length.



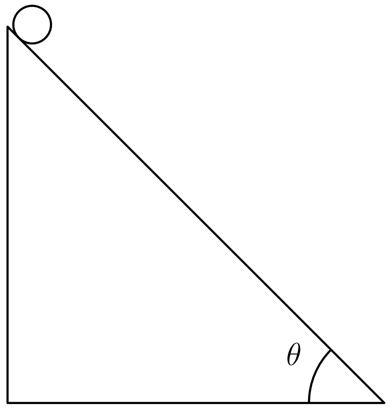
This system can also oscillate vertically. Find the period P of these oscillations in terms of $m, \Delta x,$ and $g,$ the acceleration due to gravity.

5. A pendulum is made from a small stone on a massless string. The string is strong enough to support 1.5 times the weight of the stone. The pendulum is pulled back from vertical by an angle θ and released.

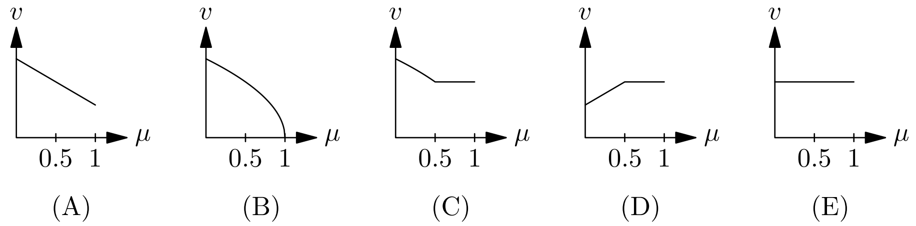


What is the largest value θ can have without breaking the string? Give your answer to the nearest degree.

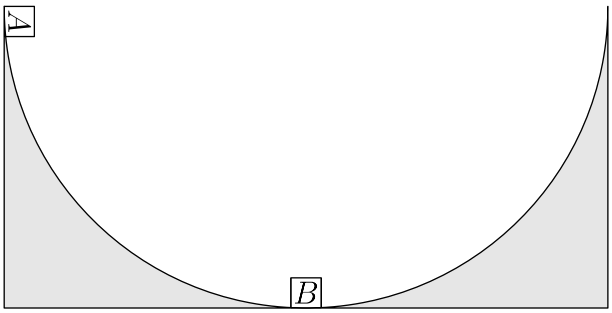
6. A hollow cylinder is released from rest at the top of a straight ramp that makes an angle $\theta = 45^\circ$ with the horizontal.



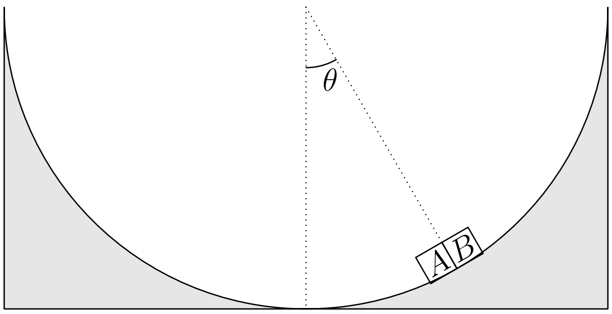
The coefficients of static and kinetic friction between the ball and ramp are both μ. There is no rolling resistance. The speed v of the cylinder is measured at the bottom of the ramp, and this experiment is repeated for different values of μ. Which graph shows v versus μ?



7. Two blocks are placed in a frictionless semi-circular trough, shown from the side below. Block A has mass m_A and is held at the top left of the trough. Block B has mass m_B and is at the bottom of the trough.

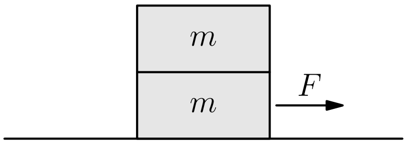


The blocks are released. Block A slides down the trough, hits block B, and sticks to it. Together, to two block rise up through an angle $\theta = 30^\circ$ to the right in the trough.

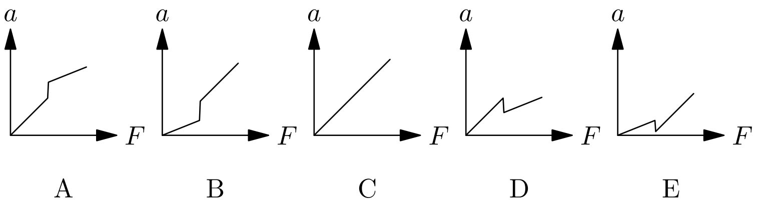


Assume that the blocks are small compared to the radius of the trough. What is the ratio $\frac{m_A}{m_B}$? Give your answer as a decimal to the nearest tenth.

8. Two blocks, each of mass m, are placed one atop the other. The bottom block rests on a frictionless table. The coefficient of static friction between the blocks is μ_s and the coefficient of kinetic friction is μ_k, and $\mu_k < \mu_s$. A constant force F is applied horizontally to the lower block.



Which plot could show the initial acceleration a of the lower block as a function of F?

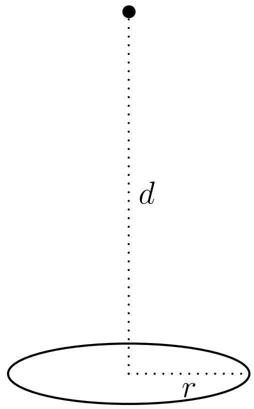


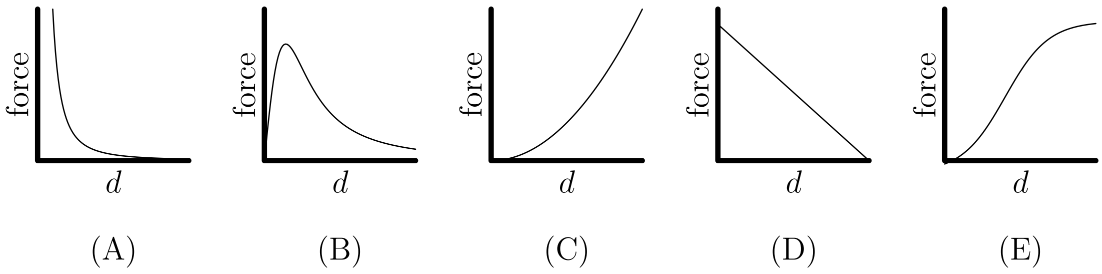
9. While on a plane, you hold a pendulum in front of you. The plane begins at rest, then accelerates down the runway with constant acceleration. During the acceleration, the pendulum is angled back toward you at an angle of $17°$ degrees from the vertical. This angle remains steady for 30 s before the plane takes off. How far along the runway did the plane travel before taking off? Give your answer to the nearest hundred meters and assume $g = 10\text{ m/s}^2$.

10. A solid disk of radius r is spinning with angular frequency ω. It is placed on top another solid disk, at the center of the second disk. The second disk is made of the same material and thickness as the first disk, but its radius is $2r$. This larger disk is initially stationary and sits on a frictionless table. There is kinetic friction between the disks. What is the final angular velocity of the large disk in terms of ω?

11. You build a small boat, place a stone in the boat, and float the boat in a cup of water. You mark the water level on the side of the cup. Then you take the stone off the boat and drop it into the water, where it sinks to the bottom of the cup. Finally, you mark the water level again. Is your second mark above, below, or even with your first one?

12. Consider a circular ring with radius r and negligible thickness. A point particle sits at some distance d from the center of the ring on the symmetry axis of the ring. Which of the following is a plot of the magnitude of the net gravitational force on the point particle from the ring as a function of d?





13. Which is an expression for the magnitude of the net gravitational force on the point particle described in the previous problem? Let the total mass of the ring be M and the mass of the point particle be m.

You may want to solve this problem via process of elimination.

(A) $\frac{GMm}{d^2}$

(B) $\frac{GMmd}{r^2 + d^3}$

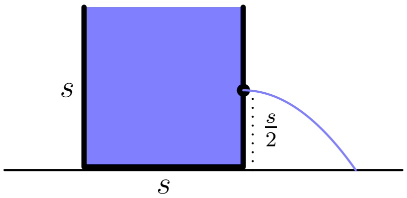
(C) $\frac{GMmd}{r^{3/2}}$

(D) $\frac{GMmd^{3/2}}{(r^2 + d^2)^2}$

(E) $\frac{GMmd}{(r^2 + d^2)^{3/2}}$

14. Shown below is a cube of side length s with an open top sitting on a frictionless surface. The cube is filled to the top with water. A small hole of area A is poked in the center of one side of the cube, allowing water to shoot out. At the moment the water begins shooting out of the hole, what is the speed of the water?

    You may assume that all the water leaves the hole with the same velocity, the cross-sectional area of the stream leaving the hole is A, the density of the water is ρ, and that frictional effects in the water can be ignored. Local gravitational acceleration is g.



Don’t look at the next page until you’ve attempted all the problems!

Solutions

1. The answer should be between $98\ \mathrm{m}$ and $104\ \mathrm{m}$.

   The answer can be counted as correct if it does not include the symbol m for meters, but please remind the student to include this symbol in the future.

2. $2.5\ \mathrm{m/s^2}$

3. $mr = MR$

4. $P = 2\pi\sqrt{\dfrac{\Delta x}{g}}.$

5. 41°

   Answers with more digits, such as 41.4°, can be counted as correct, but please remind the student to round according to the problem's instructions in the future.

6. C

7. 0.6

   Answers with more digits, such as 0.58, can be counted as correct, but please remind the student to round according to the problem's instructions.

8. B

   problem source: F=ma exam, 2020

9. $1400\ \mathrm{m}.$

   Give credit to answers that omit the symbol m or give more decimal places (e.g. 1376), but please remind students about these details for future problems.

10. $\dfrac{\omega}{17}$

11. below

12. B

13. E

14. $\sqrt{gs}$