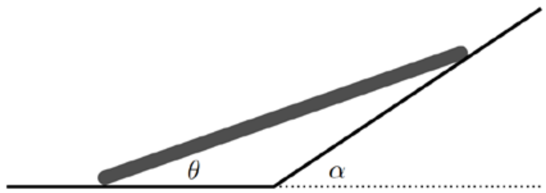
The softest audible sound has an intensity of $I_0 = 10^{-12}$ W/m^2. In terms of the fundamental units of kilograms, meters, and seconds, this is equivalent to

(A) $I_0 = 10^{-12}$ kg/s^3
(B) $I_0 = 10^{-12}$ kg/s
(C) $I_0 = 10^{-12}$ kg^{2}m/s
(D) $I_0 = 10^{-12}$ kg^{2}m/s^2
(E) $I_0 = 10^{-12}$ kg/m $\cdot$ s^3

A rod moves freely between the horizontal floor and the slanted wall. When the end in contact with the floor is moving at v, what is the speed of the end in contact with the wall?



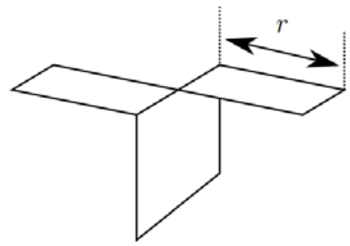
(A) $v\dfrac{\sin\theta}{\cos(\alpha-\theta)}$.
(B) $v\dfrac{\sin(\alpha-\theta)}{\cos(\alpha+\theta)}$.
(C) $v\dfrac{\cos(\alpha-\theta)}{\sin(\alpha+\theta)}$.
(D) $v\dfrac{\cos\theta}{\cos(\alpha-\theta)}$.
(E) $v\dfrac{\sin\theta}{\cos(\alpha+\theta)}$.

A flywheel can rotate in order to store kinetic energy. The flywheel is a uniform disk made of a material with a density ρ and tensile strength σ (measured in Pascals), a radius r, and a thickness h. The flywheel is rotating at the maximum possible angular velocity so that it does not break. Which of the following expression correctly gives the maximum kinetic energy per kilogram that can be stored in the flywheel? Assume that α is a dimensionless constant.

(A) $\alpha\sqrt{\rho\sigma/r}$
(B) $\alpha h\sqrt{\rho\sigma/r}$
(C) $\alpha\sqrt{(h/r)}(\sigma/\rho)^2$
(D) $\alpha(h/r)(\sigma/\rho)$
(E) $\alpha\sigma/\rho$

The following information applies to questions 12 and 13

A paper helicopter with rotor radius r and weight W is dropped from a height h in air with a density of ρ.



Assuming that the helicopter quickly reaches terminal velocity, a function for the time of flight T can be found in the form

$$T = kh^{\alpha}r^{\beta}\rho^{\delta}W^{\omega}.$$

where k is an unknown dimensionless constant (actually, 1.164). α, β, δ, and ω are constant exponents to be determined.

12. Determine α.

    (A) $\alpha = -1$
    (B) $\alpha = -1/2$
    (C) $\alpha = 0$
    (D) $\alpha = 1/2$
    (E) $\alpha = 1$

13. Determine β.

    (A) $\beta = 1/3$
    (B) $\beta = 1/2$
    (C) $\beta = 2/3$
    (D) $\beta = 1$
    (E) β can not be uniquely determined without more information.

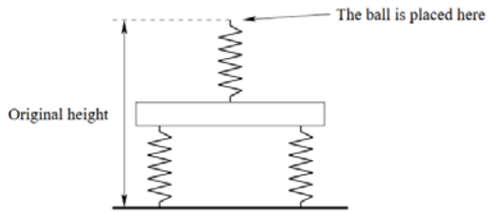
Inspired by a problem from the 2012 International Physics Olympiad, Estonia.

A very large number of small particles forms a spherical cloud. Initially they are at rest, have uniform mass density per unit volume ρ_0, and occupy a region of radius r_0. The cloud collapses due to gravitation; the particles do not interact with each other in any other way.

How much time passes until the cloud collapses fully? (The constant 0.5427 is actually $\sqrt{\frac{3\pi}{32}}$.)

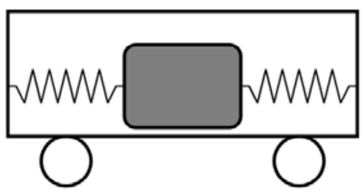
(A) $\frac{0.5427}{{r_0}^2\sqrt{G\rho_0}}$
(B) $\frac{0.5427}{r_0\sqrt{G\rho_0}}$
(C) $\frac{0.5427}{\sqrt{r_0}\sqrt{G\rho_0}}$
(D) $\frac{0.5427}{\sqrt{G\rho_0}}$
(E) $\frac{0.5427}{\sqrt{G\rho_0}}r_0$

21. A spring system is set up as follows: a platform with a weight of 10 N is on top of two springs, each with spring constant 75N/m. On top of the platform is a third spring with spring constant 75N/m. If a ball with a weight of 5.0 N is then fastened to the top of the third spring and then slowly lowered, by how much does the height of the spring system change?



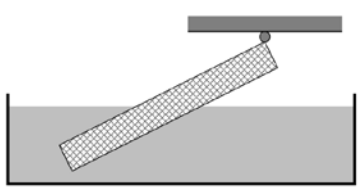
(A) 0.033 m
(B) 0.067 m
(C) 0.100 m
(D) 0.133 m
(E) 0.600 m

Inside a cart that is accelerating horizontally at acceleration $\vec{a}$, there is a block of mass M connected to two light springs of force constants k_1 and k_2. The block can move without friction horizontally. Find the vibration frequency of the block.



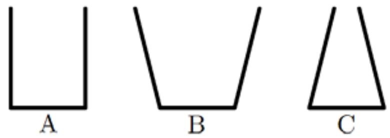
(A) $\frac{1}{2\pi}\sqrt{\frac{k_1+k_2}{M}+a}$
(B) $\frac{1}{2\pi}\sqrt{\frac{k_1k_2}{(k_1+k_2)M}}$
(C) $\frac{1}{2\pi}\sqrt{\frac{k_1k_2}{(k_1+k_2)M}+a}$
(D) $\frac{1}{2\pi}\sqrt{\frac{|k_1-k_2|}{M}}$
(E) $\frac{1}{2\pi}\sqrt{\frac{k_1+k_2}{M}}$

15. A uniform rod is partially in water with one end suspended, as shown in figure. The density of the rod is 5/9 that of water. At equilibrium, what portion of the rod is above water?



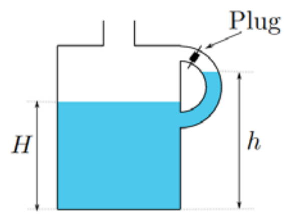
(A) 0.25
(B) 0.33
(C) 0.5
(D) 0.67
(E) 0.75

9. Flasks A, B, and C each have a circular base with a radius of 2 cm. An equal volume of water is poured into each flask, and none overflow. Rank the force of water F on the base of the flask from greatest to least.



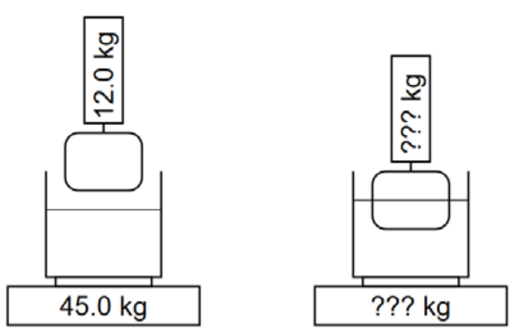
(A) $F_A > F_B > F_C$
(B) $F_A > F_C > F_B$
(C) $F_B > F_C > F_A$
(D) $F_C > F_A > F_B$
(E) $F_A = F_B = F_C$

10. The handle of a gallon of milk is plugged by a manufacturing defect. After removing the cap and pouring out some milk, the level of milk in the main part of the jug is lower than in the handle, as shown in the figure. Which statement is true of the gauge pressure P of the milk at the bottom of the jug? ρ is the density of the milk.



(A) $P = \rho g h$
(B) $P = \rho g H$
(C) $\rho g H < P < \rho g h$
(D) $P > \rho g h$
(E) $P < \rho g H$

20. A container of water is sitting on a scale. Originally, the scale reads $M_1 = 45$ kg. A block of wood is suspended from a second scale; originally the scale read $M_2 = 12$ kg. The density of wood is 0.60 g/cm^3; the density of the water is 1.00 g/cm^3. The block of wood is lowered into the water until half of the block is beneath the surface. What is the resulting reading on the scales?



(A) $M_1 = 45$ kg and $M_2 = 2$ kg.
(B) $M_1 = 45$ kg and $M_2 = 6$ kg.
(C) $M_1 = 45$ kg and $M_2 = 10$ kg.
(D) $M_1 = 55$ kg and $M_2 = 6$ kg.
(E) $M_1 = 55$ kg and $M_2 = 2$ kg.