ADVANCED PHYSICS CLUB

JANUARY 21, 2024

Useful resources

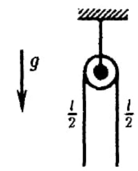
The updates, homework assignments, and useful links for APC can be found on SchoolNova's web page:
`https://schoolnova.org/nova/classinfo?class_id=adv_phy_club&sem_id=ay2020`
The practical information about the club and contacts can be found on the same web page.

Today's meeting

We solved most of the assigned problems on energy conservation law, the remaining problems are reassigned. The new topic is simple harmonic motion.

Reassigned Homework

***6.** A uniform smooth rope of mass m and total length l is initially at rest hanging on a small pulley in equilibrium, with exactly $l/2$ on each side, as shown on the figure. Then the rope is displaced just a bit and as a result it starts moving. With what force does the rope act on the pulley when its' length on one side is $l/3$?



2. Consider two balls: one of mass m_1 moving with velocity $\vec{v}_1$ and another of mass m_2 moving with velocity $\vec{v}_2$. Write their total kinetic energy as $E_{COM} + E_{extra}$, where E_{COM} is the kinetic energy of the center of mass (defined as the kinetic energy of an object having the same mass as the whole system and the same speed as the center of mass). What is E_{extra} in the above decomposition equal to? How does it relate to the maximal amount of heat that can be generated in a collision of m_1 with m_2?

3. *(Inspired by personal experience)* A cross-country skier goes down one hill and directly up another hill. Lazy after a long day of skiing, the skier wants to avoid doing extra work on the way up and tries to simply slide up the hill by inertia, without using his legs or his poles. It doesn't work and he stops a mere 0.3 meters (if measured vertically) below the top of the hill. On the next attempt the skier tries taking a seated position on the way up. Can it help reach the top? If yes, has the skier actually avoided doing any work to get to the top of the hill? Neglect air resistance and assume that the initial speed of the skier at the top of the first hill (before going down) is the same in both attempts. The height of the skier is 1.8 meters. You may choose to neglect friction or to try to take into it account, assuming the friction coefficient to be constant.

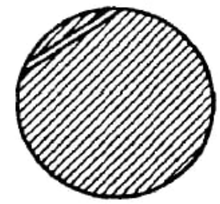
***4.** A car engine burns gasoline to convert its chemical energy into the kinetic energy of the car. In order to get to speed v from rest a car of mass m requires gasoline of volume V. The sensible process of energy conversion however starts looking very puzzling from the perspective of a train passenger if the train is moving in the same direction as the car but with constant speed v (same as the final speed of the car). In the reference frame of the train the car initially moves with speed v in the opposite direction and then gradually comes to a stop. In other words, its' kinetic energy decreases! But surely in this reference frame the car burns the same amount of gasoline. How to reconcile this with energy conservation?

New Homework

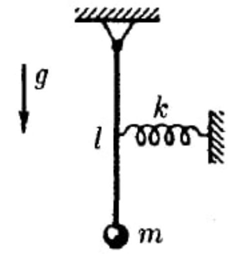
1. Solve the following problems from the previous F = ma exams:
   (a) 16, 18 (2009: `https://www.aapt.org/physicsteam/2010/upload/2009_F-ma.pdf`)
   (b) 15, 19, 20 (2011: `https://www.aapt.org/physicsteam/2012/upload/WebAssign-exam1-2011-1-4.pdf`)
   (c) 16, 18 (2011: `https://www.aapt.org/physicsteam/2013/upload/exam1-2012-unlocked.pdf`)

2. A block hanging still on a vertical spring extends it by length l. Find the period of small vertical oscillations of the suspended block.

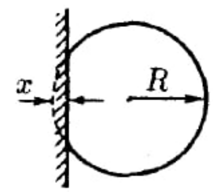
3. A straight tunnel is dug through the Earth, not passing through its center. How long would it take a train with engine off to travel from one end to the other end in such a tunnel? Neglect friction and air resistance.



4. A pendulum consists of a weight of mass m at the end of a light rigid rod of length l. A horizontal spring with spring constant k it attached to the center of the rod. Find the frequency of small oscillations of the system. The diagram shows the equilibrium position.



***5.** A spherical balloon is deformed as shown on the figure during a collision with a wall, so that the maximal value of the deformation x is much less than the radius R. Estimate the time of the collision. Mass of the balloon is m. The pressure inside the balloon exceeds the atmospheric pressure by Δp, the change in pressure during the collision can be neglected.



For the next meeting

IMPORTANT: The next club's meeting is at 3:30pm, via Zoom, on Sunday, **January 28**.